2006 FINAL PROJECT REPORT

Microbial Source Tracking And Virginia's Beach Monitoring Program

MEMORANDUM OF AGREEMENT (No. 601-617-93275-2006-VA Tech)

Between

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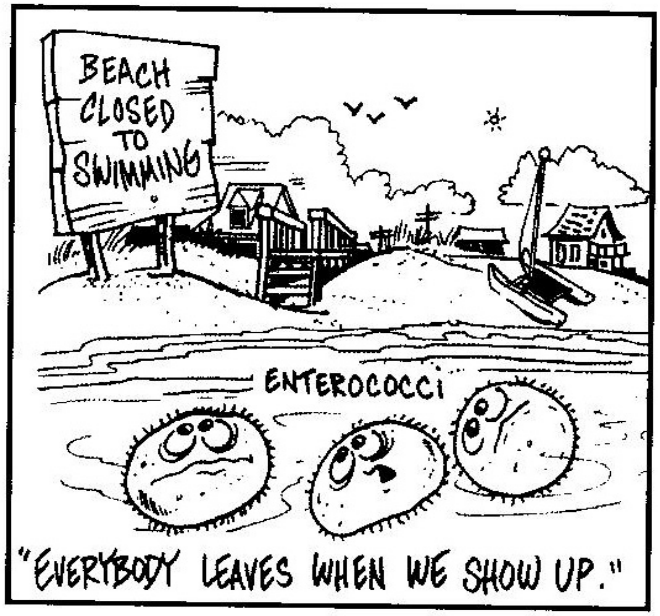


Project Summary

Virginia's beaches were in better condition in 2006 than they had been in 2005 or 2004, and the VDH sampling in 2006 resulted in fewer total health advisories (see links to 2006 beach statistics at http://www.vdh.state.va.us/epidemiology/dzee/beachmonitoring/). Only three beaches had advisories in 2006 (Fairview, Huntington, and Virginia Beach). Combined, the three beaches had eight advisories and a total of 43 days under advisory, with Fairview accounting for 33 (77%) of the 43 days under advisory in 2006 (4 days for Huntington and 6 days for Virginia Beach). By comparison, in 2004 there were seven beaches with a total of 26 advisories and 145 days under advisory, while in 2005 there were 12 advisories at five beaches and 38 days under advisory. If Fairview is excluded, there is a clear trend towards fewer advisories and days under advisory from 2004 through 2006. This is due in part to beach restoration projects at many beaches that were damaged by Hurricane Isabel in September, 2003. Also, the VT staff deployed Microbial Source Tracking (MST) to classify isolates of *Enterococcus* as being from humans, birds, dogs, or wildlife sources, and fluorometry (detection of optical brighteners in detergents from sewers and septic drainfields) was added as a chemical method to differentiate between human and non-human sources of pollution. Based on the 2004 results that human sources of pollution were present at several beaches, investigations by officials from Hampton, Newport News, and Hampton Roads Sanitation District identified probable sources of the pollution and took steps to eliminate the problems. Sampling in 2005 and 2006 confirmed the success of these efforts (reduction in the level of pollution from human sources) and demonstrated improved water quality conditions at beaches where post-hurricane restoration projects were undertaken. Hilton, King-Lincoln, and Anderson Beaches all had advisories in 2004 and 2005, but none in 2006. This demonstrated the success of using MST to identify sources of fecal pollution in 2004, performing remediation to remove the origins of the pollution in 2005, and then following-up with MST in 2006 to prove that the sources found in 2004 and 2005 were no longer present in 2006. This is the first report where MST results indicated pollution from a particular source was present (human-origin sewage), the origin of the pollution was then located, steps were taken to eliminate the pollution, and subsequent MST results indicated the success of those remediation efforts. The 2007 project will focus on the three beaches that had advisories in 2006.

Fairview Beach is especially problematic as there was a persistent human signature at all three VDH sampling locations in 2006, and efforts to determine the sources of it will be a focus at Fairview Beach in 2007. It appears that precipitation is the cause of many of the problems at Fairview Beach, and a storm drain near the public swimming area is frequently the source of high levels of enterococci. Fairview Beach suffered yet another setback in 2006, much of the beach restoration work that had been performed in 2005 and 2006 was damaged by tropical storm Ernesto in September, 2006. For any advisories that occur in 2007, MST will be performed as rapidly as possible and, if human-origin isolates are found, then an immediate follow-up trip will occur so that intensive sampling can be performed in an effort to locate the sources of the human-origin pollution with a combination of MST and fluorometry.

For Huntington Beach, sampling will concentrate on the waters around a public boat ramp that appeared to be associated with the advisories at Huntington in 2006. The boat ramp is upstream from the swimming area and this may have helped pollution from the boat ramp area move into the swimming zone. Careful attention to the activities of boaters by officials to prevent waste dumping in the water should help improve water quality and eliminate advisories at this beach.

For Virginia Beach, the VT lab will continue to work with Hampton Roads Sanitation District (HRSD) and will employ MST in 2007 to determine the sources of enterococci in the discharges, outfalls, beach sand, and wet wells at 79th and 63rd Streets, the only two remaining open storm-water discharges at Virginia Beach (and the locations of all 3 advisories in 2006). A grid system will be used after major precipitation events to collect samples in the ocean in front of the outfalls. This grid system was successfully used by the VT staff at other beaches in 2005 to determine the direction of pollution in the water. Also, in 2007 the beach sand within the discharge areas will be sampled to determine if it is acting as a reservoir for enterococci where either re-growth or longer-term survival (that could impact beach water quality) might occur.

1. Peninsula Health District

1. A. King-Lincoln Park Beach

King-Lincoln Beach is approximately 300-yards long, although the exact boundaries are not apparent. The beach extends southwest to northeast along the North Bank of the James River. The park is flanked on the north by the Aqua Vista apartment complex (adjacent to roughly 50 yards of beach) and contains a wooden pier on the northern end that was destroyed by Hurricane Isabel in 2003 but was rebuilt by the summer of 2005. The remaining 250 or so yards of this beach are south of the pier and adjacent to King-Lincoln Park. People rarely swim in the water at this beach and the shoreline is not in good condition, but fishing activity has increased with the new pier and substantial numbers of shore birds were observed around or on the pier in 2005 and 2006. Samples were taken weekly over the 2005 beach season by the Peninsula Health District staff at the northeastern end of the beach just north of the pier. Additional samples were collected twice a month for three months by the VT staff, from June through August, at the northern side of the pier (same as the VDH sampling location, King-Lincoln B) and from the storm drain (King-Lincoln SW) that is located on the northern side of the pier. The site on the southern side of the pier (King-Lincoln A) was sampled multiple times in 2004 and 2005 and never produced high counts or optical brighteners, so it was not sampled in 2006. King-Lincoln Park posted three advisories in 2004, three in 2005, and none in 2006.

For the four tables on the following pages (monitoring and source tracking results for each of the two sampling sites), the date followed by an "A" (for example, 0606A) indicates that the sample was collected in June, 2006, the second week of each month, June through August, and the date followed by a "B" indicates the sample was collected the fourth week of each month. For King-Lincoln B (northern side of the pier) there were no counts that exceeded the standard (Table 1), and the major source of the *Enterococcus* isolates was birds (67.9% of the total), with dogs and wildlife as secondary sources (17.8% and 14.3%, respectively, Table 2). No isolates were classified as human in origin. MST was performed on only two of the six samples collected as counts for four of the samples were too low (<10, Table 1).

For King-Lincoln SW (storm drain outfall on northern side of the pier), no counts exceeded the standard, Table 3), and the major source of the *Enterococcus* isolates was birds (59.5% of the total), with dogs and wildlife as the secondary sources (21.7% and 18.8%, respectively, Table 4).

During the summer and fall of 2005, city engineers worked extensively on the storm drain system from the Aqua Vista apartment complex to identify and resolve cross-connections with the sewer system, collect and remove trash and debris that clogged some drains, and redirect stream water that could enter the storm drains during high rainfall events. These efforts

Table 1. Monitoring results for King-Lincoln B.

Collection Date	Location*	Optical Brightener	Tidal Level	cfu/100mL
0606A**	King-Lincoln B	27	Mid-out	17
0606B	King-Lincoln B	31	High-out	<10
0706A	King-Lincoln B	23	High-out	14
0706B	King-Lincoln B	29	High	<10
0806A	King-Lincoln B	22	Low-out	<10
0806B	King-Lincoln B	30	High –in	<10

*King-Lincoln B collected from the northern side of the pier.
**Sample A collected 2nd week and sample B collected 4th week of each month.

Table 2. Monitoring results for King-Lincoln SW.

Collection Date	Location*	Optical Brightener	Tidal Level	cfu/100mL
0606A**	King-Lincoln SW	30	High-in	46
0606B	King-Lincoln SW	23	Low-out	<10
0706A	King-Lincoln SW	25	Mid-out	37
0706B	King-Lincoln SW	42	High-out	<10
0806A	King-Lincoln SW	33	High-out	<10
0806B	King-Lincoln SW	21	High	<10

*King-Lincoln B collected from the northern side of the pier.
**Sample A collected 2nd week and sample B collected 4th week of each month.

contributed to the lack of flow from the storm drain outfall on the beach for both 2005 and 2006, and the success of those efforts is indicated by the lack of advisories and high counts at King-Lincoln Park Beach in 2006.

Fluorometry results (detection of optical brighteners [OB] from detergents) were negative for all samples from the storm drain outfall and the beach. However, this beach may still experience occasional advisories as dog wastes were frequently observed on the northern part of the beach near the apartments and shore birds appeared to be attracted to the fishing pier, especially to trash that had been left on the pier.

Table 3. Microbial source tracking results for King-Lincoln B.

Collection Date	Location*	Bird	Human	Dogs	Wildlife	Total
0606A**	King-Lincoln B	9	0	4	3	16
0606B	King-Lincoln B	0	0	0	0	0
0706A	King-Lincoln B	10	0	1	1	12
0706B	King-Lincoln B	0	0	0	0	0
0806A	King-Lincoln B	0	0	0	0	0
0806B	King-Lincoln B	0	0	0	0	0
Total	**King-Lincoln B**	**19**	**0**	**5**	**4**	**28**
%		**67.9**	**0.0**	**17.8**	**14.3**	

*King-Lincoln SW collected from the storm drain outfall.
**Sample A collected 2nd week and sample B collected 4th week of each month.

Table 4. Microbial source tracking results for King-Lincoln SW.

Collection Date	Location*	Bird	Human	Dogs	Wildlife	Total
0606A**	King-Lincoln SW	9	0	4	3	16
0606B	King-Lincoln SW	0	0	0	0	0
0706A	King-Lincoln SW	10	0	3	3	16
0706B	King-Lincoln SW	0	0	0	0	0
0806A	King-Lincoln SW	0	0	0	0	0
0806B	King-Lincoln SW	0	0	0	0	0
Total	**King-Lincoln SW**	**19**	**0**	**7**	**6**	**32**
%		**59.5**	**0.0**	**21.7**	**18.8**	

*King-Lincoln SW collected from the storm drain outfall.
**Sample A collected 2nd week and sample B collected 4th week of each month.

Plans for King-Lincoln Park Beach in 2007

The sampling in 2006 indicated that the storm drain and birds attracted to the fishing pier did not negatively impact water quality. Problems with the storm drain appear to have been successfully addressed. No monitoring at this beach, other than what is planned by VDH staff, will be needed in 2007 unless advisories occur.

Image 1. The new fishing pier built at King-Lincoln Park in early 2005. Structures like piers attract birds, especially when trash is dumped on the end of the pier. Trash receptacles were added in 2006.

Image 2. Northern part of the beach area between the pier and the apartments. The beach was often littered with trash, including soiled diapers and dog wastes. The storm drain is out of sight to the left.

1. B. Anderson Park Beach

Anderson Beach is approximately 600-yards long, although the exact boundaries are not apparent when walking the beach. The beach extends southwest to northeast along the North Bank of the James River. The park is flanked on the north by a waterway that leads into a small marina called Peterson's Yacht Basin. A small park (Monitor-Merrimac Overlook) with a fishing pier is just NE of the entrance to the yacht basin. Several large apartment complexes (Christopher's Shores and Stuart Gardens) are adjacent to the beach area. Anderson Park Beach borders King-Lincoln Park on the SW end, but there is no direct connection and the actual boundaries are not clear. People rarely swim in the water at this beach, the shoreline is not in good condition, and large numbers of shore birds were frequently observed on various parts of the beach. Samples were taken weekly over the 2004, 2005, and 2006 beach seasons by the Peninsula Health District staff at one central location on the beach (designated as Anderson A). Additional samples were collected twice a month for three months by the VT staff in 2006, June through August, from the single location used by the VDH staff, and a second location from a storm drain outfall near the NE end of the beach, north of Anderson A (and is submerged at high tide, designated as Anderson NE). Anderson Beach posted four swimming advisories during the summer of 2004, but only one swimming advisory in 2005 (occurred in late May), and none in 2006. In the fall of 2004, a large concentration of optical brighteners was found in the water above Anderson NE and below the entrance to the marina. Based on these results, city engineers excavated into an old sewer line that was no longer in use adjacent to the shore. They found that the cap sealing off the old sewer line had failed (apparently several years ago), resulting in raw sewage entering the old sewer line and then seeping out into the water above the beach area. The old line was permanently closed and sealed, resulting in the disappearance of the optical brighteners in the water. This contributed greatly to the lower number of advisories at Anderson Beach in 2005 and no advisories in 2006. With no advisories, a third location that was sampled in 2005 by the VT staff (designated Anderson B) 50 yards south of Anderson A, was not included in the 2006 sampling.

For the four tables on the following pages (monitoring and source tracking results for each of the two sampling sites), the date followed by an "A" (for example, 0606A) indicates that the sample was collected in June, 2006, the second week of each month (A), June thru August, and the date followed by a "B" indicates the sample was collected the fourth week of each month. For Anderson A, no samples exceeded the standard and 4 of the 6 samples were less than ten (Table 1). Source tracking was not performed on samples where the monitoring counts were less than 10. The major sources of the *Enterococcus* isolates were birds (67.8% of the total, Table 3), with wildlife and dogs as secondary sources (21.5 and 10.7%, respectively, Table 3). No isolates were classified as human in origin.

For Anderson NE (storm drain outfall), no samples exceeded the standard, counts were obtained from only three samples, and one of those was less than 10 (Table 2). The major sources of the *Enterococcus* isolates were birds (71.8% of the total, Table 4), with dogs and wildlife as the secondary sources (21.9% and 6.3%, respectively, Table 4). No isolates were classified as human in origin.

Table 1. Monitoring results for Anderson A.

Collection Date	Location*	Optical Brighteners	Tidal Level	cfu/100mL
0606A**	Anderson A	33	High-in	12
0606B	Anderson A	29	Low-in	<10
0706A	Anderson A	25	Mid - out	<10
0706B	Anderson A	31	Low -out	<10
0806A	Anderson A	22	High -out	<10
0806B	Anderson A	25	Low	17

*Anderson A is where the VDH staff collect samples.
**Sample A collected 2nd week and sample B collected 4th week of each month.

Table 2. Monitoring results for Anderson NE.

Collection Date	Location*	Optical Brightener	Tidal Level	cfu/100mL
0606A**	Anderson NE	38	High-in	32
0606B	Anderson NE	24	Low-in	0
0706A	Anderson NE	31	Mid – out	<10
0706B	Anderson NE	34	Low -out	0
0806A	Anderson NE	22	High -out	26
0806B	Anderson NE	32	Low	0

*Anderson NE collected from the storm drain outfall.
**Sample A collected 2nd week and sample B collected 4th week of each month.

Table 3. Microbial source tracking results for Anderson A.

Collection Date	Location*	Bird	Human	Dogs	Wildlife	Total
0606A**	Anderson A	9	0	1	2	12
0606B	Anderson A	0	0	0	0	0
0706A	Anderson A	0	0	0	0	0
0706B	Anderson A	0	0	0	0	0
0806A	Anderson A	0	0	0	0	0
0806B	Anderson A	10	0	2	4	16
Total	Anderson A	**19**	**0**	**3**	**6**	**28**
%		**67.8**	**0.0**	**10.7**	**21.5**	**100**

*Anderson A is where the VDH staff collect samples.
**Sample A collected 2nd week and sample B collected 4th week of each month.

Table 4. Microbial source tracking results for Anderson NE.

Collection Date	Location*	Bird	Human	Dogs	Wildlife	Total
0606A**	Anderson NE	11	0	4	1	16
0606B	Anderson NE	0	0	0	0	0
0706A	Anderson NE	0	0	0	0	0
0706B	Anderson NE	0	0	0	0	0
0806A	Anderson NE	12	0	3	1	16
0806B	Anderson NE	0	0	0	0	0
Total	Anderson NE	**23**	**0**	**7**	**2**	**32**
%		**71.8**	**0.0**	**21.9**	**6.3**	**100**

*Anderson NE collected from the storm drain outfall.
**Sample A collected 2nd week and sample B collected 4th week of each month.

The storm drain was clearly not a problem at Anderson Beach in 2006, as compared to 2005 where seven samples exceeded the standard and ranged from 220 to 5,040 CFU/100 mL. Fluorometry results (detection of optical brighteners [OB] from detergents) were all negative (below 100) in 2006. City engineers worked throughout 2005 to improve drainage at the beach and the housing complex adjacent to the beach, and reduce the discharge from the storm drain. It appears that these efforts were successful. In summary, it appears that the repairs to the leaking sewer line in 2004 reduced both the counts and the magnitude of the human signature in water samples taken at Anderson Beach in 2005. This resulted in fewer advisories in 2005 as compared to 2004. It also appears that improving drainage and reducing the amount of water that entered the storm drain in 2005 reduced both the counts and the magnitude of the human signature in water samples taken at Anderson Beach in 2006. This resulted in no advisories in 2006. Two years of repairs resulted in the first summer at Anderson Beach when there were no advisories.

Plans for Anderson Beach in 2007

Problems with the storm drain and the leaking sewer appear to have been successfully addressed. No monitoring at this beach, other than what is planned by VDH staff, will be needed in 2007 unless advisories occur.

Image 1. Anderson A sampling site location, in between the first and second jetties in the picture.

Trash receptacles are needed here. The view is looking south, and the storm drain is out of site to the north of where the picture was taken.

Image 2. Michele Monti collecting a sample from the storm drain, August 2005.

1. C. Hilton Beach

Hilton Beach is approximately 100 yards in length, running west to east along the northern bank of the James River. Located behind an elementary school, Hilton Beach is almost completely covered at high tide, and contains a continuously flowing storm drain outfall on the easternmost side of the beach. One sample was collected from Hilton Beach each week from a central location by VDH staff over the 2004, 2005, and 2006 beach seasons, west of the storm drain (identified as Hilton 208). In 2006, additional samples were collected twice a month for three months by the VT staff, June through August, from the storm drain outfall on the eastern end of the beach (Hilton SW), and from the central area of the beach (same as the VDH sampling location, Hilton 208).

Hilton Beach posted four swimming advisories and was closed for a total of 63 days in the summer of 2004; there were three swimming advisories posted for the summer of 2005, but the beach was closed for only 8 days. There were no advisories in 2006. People rarely swim in the water at this beach, and dogs appear to be a problem at certain times as people were observed walking their dogs directly on the beach area. Less of this was observed in 2006 as compared to previous years. The beach is almost totally submerged at high tide, and any dog wastes left on the beach then become dispersed in the water. Hilton Beach was the most problematic beach of those monitored in 2004, likely due to the storm drain outfall on the eastern end of the beach. In the fall of 2004, city officials discovered sewer pipes from a nearby trailer park that were leaking into the Hilton storm drain, contributing the high human signature obtained during the summer of 2004. Plans were made to repair the storm drain system prior to the 2005 swimming season, and these repairs were made over the spring, summer, and fall of 2005. The repairs resulted in a reduction of advisories and days under closure from 2004 to 2005, and eliminated the advisories altogether in 2006. Fishing activity increased with the new pier constructed in 2005 and small but persistent numbers of shore birds were frequently observed around or on the pier in 2006. These birds did not appear to have any impact on water quality at Hilton Beach in 2006.

For the four tables on the following pages (monitoring and source tracking results for each of the two sampling sites), the date followed by an “A” (for example, 0606A) indicates that the sample was collected in June, 2006, on the second week of each month (A), June thru August, and the date followed by a “B” indicates the sample was collected the fourth week of each month. For Hilton 208 (VDH site - central location of the beach) there were no samples that exceeded the standard (Table 1), and the major sources of the *Enterococcus* isolates were birds (62.4% of the total, Table 3), with wildlife and dogs as secondary sources (18.8% for each, Table 4). No isolates were classified as human in origin. The bi-weekly sampling by the VT staff produced monitoring results that were in close agreement with the samples collected by the VDH staff.

For Hilton SW (storm drain outfall on eastern side of the beach) there were also no samples that exceeded the standard (Table 2), and the major sources of the *Enterococcus* isolates were birds (68.8% of the total, Table 4), with wildlife, and dogs as secondary sources (16.7%, and 14.5%, respectively, Table 4). No isolates were classified as human in origin for 2006, a significant difference from 2004 and 2005, when isolates of human origin were routinely found in the high *Enterococcus* populations that were recovered from the storm drain.

Table 1. Monitoring results for Hilton 208.

Collection Date	Location*	Optical Brightener	Tidal Level	cfu/100mL
0606A**	Hilton 208	32	Low-out	28
0606B	Hilton 208	45	Low-in	31
0706A	Hilton 208	28	Mid-in	<10
0706B	Hilton 208	39	Low-out	<10
0806A	Hilton 208	25	Mid-out	<10
0806B	Hilton 208	24	Low-in	17

*Hilton 208 collected from the center of the beach area.
**Sample A collected 2nd week and sample B collected 4th week of each month.

Table 2. Monitoring results for Hilton SW.

Collection Date	Location*	Optical Brightener	Tidal Level	cfu/100mL
0606A**	Hilton SW	45	Low-out	64
0606B	Hilton SW	27	Low-in	68
0706A	Hilton SW	26	Mid-in	36
0706B	Hilton SW	44	Low-out	76
0806A	Hilton SW	69	Mid-out	85
0806B	Hilton SW	32	Low-in	41

*Hilton SW collected from the storm drain outfall.
**Sample A collected 2nd week and sample B collected 4th week of each month.

Since VT and VDH began monitoring together in 2004, Hilton Beach has been one of the worst beaches for water quality as reflected in advisories in 2004 and 2005. For the storm drain outfall, four samples had counts greater than 1,000 in 2005 and two samples had counts higher than 40,000. Fluorometry results (detection of optical brighteners [OB] from detergents) were positive for OBs from the same two samples with the very high counts. The absence of advisories, lack of high counts, and no OBs detected in 2006 attests to the success by city engineers of finding and correcting the sewer problems associated with the mobile home park and the storm drain. In summary, it appears that the alterations to the storm drain system reduced human-origin water contamination between 2004 and 2005, and eliminated it altogether in 2006. Water quality at Hilton Beach is in better condition now than at any time since work on this beach began in 2004.

Table 3. Microbial source tracking results for Hilton 208.

Collection Date	Location*	Bird	Human	Dogs	Wildlife	Total
0606A**	Hilton 208	10	0	2	4	16
0606B	Hilton 208	11	0	2	3	16
0706A	Hilton 208	0	0	0	0	0
0706B	Hilton 208	0	0	0	0	0
0806A	Hilton 208	0	0	0	0	0
0806B	Hilton 208	9	0	5	2	16
Total	Hilton 208	**30**	**0**	**9**	**9**	**48**
%		**62.4**	**0.0**	**18.8**	**18.8**	**100**

*Hilton 208 collected from the center of the beach area.
**Sample A collected 2nd week and sample B collected 4th week of each month.

Table 4. Microbial source tracking results for Hilton SW.

Collection Date	Location*	Bird	Human	Dogs	Wildlife	Total
0606A**	Hilton SW	11	0	2	3	16
0606B	Hilton SW	10	0	1	5	16
0706A	Hilton SW	13	0	3	0	16
0706B	Hilton SW	9	0	2	5	16
0806A	Hilton SW	12	0	4	0	16
0806B	Hilton SW	11	0	2	3	16
Total	Hilton SW	**66**	**0**	**14**	**16**	**96**
%		**68.8**	**0.0**	**14.5**	**16.7**	**100**

*Hilton SW collected from the storm drain outfall.
**Sample A collected 2nd week and sample B collected 4th week of each month.

Plans for Hilton Beach in 2007

The sampling in 2006 indicated that precipitation events and birds attracted to the fishing pier did not negatively impact water quality. Problems with the storm drain appear to have been successfully addressed. No monitoring at this beach, other than what is planned by VDH staff, will be needed in 2007 unless advisories occur.

Image 1. Hilton Beach at high tide on the James River, when very little of the beach is above water. The storm drain is out of sight to the right, the fishing pier is on the western end of the beach.

Image 2. The fishing pier at Hilton Beach.

1. D. Huntington Beach

Huntington Beach is a 400yd stretch of beach located on the northern bank of the James River at the War Memorial Museum, and adjacent to the James River Bridge. Since this is a heavily used and popular beach with swimmers, three sampling sites are monitored by the Peninsula Health District along the southern end of the beach, all within a 100 yard-wide swimming area enclosed by buoys. VDH sampling sites for Huntington (labeled as 205, 206, and 207) were located within the buoyed swimming area, with 205 at the easternmost location, 207 at the westernmost, and 206 in the middle. Each sampling location was separated by approximately 40 yards, and these were sampled weekly by VDH staff over the 2004, 2005, and 2006 beach seasons. In 2006 samples were collected twice a month for three months by the VT staff, June through August, from Huntington 205, 206, and 207, and Huntington SW (a storm outfall on the east end of the beach, next to the James River Bridge).

Huntington Beach posted four swimming advisories and was closed a total of twelve days during the summer of 2004, there were no advisories in 2005, and there were two advisories in 2006, one in June for three days (6/27-6/30) and one in August for one day (8/17-8/18). Samples were provided to VT by VDH staff during both advisories. Between the 2004 and 2005 seasons, officials developed a program for regularly cleaning the beach, collecting and removing trash that might attract birds, and took a more proactive approach with dog owners to collect pet wastes. These efforts contributed to the absence of swimming advisories in 2005. Between the 2005 and 2006 seasons, officials worked to divert stormwater away from the storm drain (Huntington SW), based on our 2005 results that implicated the storm drain as a source of high counts of fecal bacteria and positive readings for optical brighteners after precipitation events.

For the eight tables on the following pages (monitoring and source tracking results for each of the four sampling sites), the date followed by an "A" (for example, 0606A) indicates that the sample was collected in June, 2006, the second week of the month (A), and the date followed by a "B" indicates the sample was collected the fourth week of each month. For Huntington 205 there were no samples that exceeded the standard (Table 1), and the major sources of the *Enterococcus* isolates from site 205 were birds (60.9% of the total, Table 5), with dogs and wildlife as minor sources (23.4% and 15.7%, respectively, Table 5). No isolates were classified as human in origin. For Huntington 206, none of the VT samples exceeded the standard but all three VDH advisory samples did (Table 2). The major sources of the *Enterococcus* isolates were birds (66.7% of the total, Table 6), with humans, wildlife, and dogs as secondary sources (15.4%, 10.8%, and 7.1%, respectively, Table 6). A few human isolates were found in the VT samples, on dates that followed the advisories, and human isolates were found in all three VDH advisory samples. For Huntington 207, none of the VT samples exceeded the standard but all three VDH advisory samples did (Table 3). The major sources of the *Enterococcus* isolates were birds (51.4% of the total, Table 7), with humans, dogs, and wildlife as secondary sources (29.5%, 13.0%, and 6.1%, respectively, Table 7). A few human isolates were found in the VT samples, on dates that followed the advisories, and human isolates were found in all three VDH advisory samples. For Huntington SW (storm drain outfall) there were no samples that exceeded the standard (Table 4), and the major sources of the *Enterococcus* isolates from site SW were birds (68.8% of the total, Table 8), with dogs and wildlife as minor sources (17.7% and 13.5%, respectively, Table 8). No isolates were classified as human in origin.

Looking at the entire beach, there were no samples that exceeded the standard at the easternmost site (205) or the storm drain (SW) that was located further east of the beach (Image 1). This indicates that the work done by officials to redirect storm water between the 2005 and

2006 season were successful. Some samples with very large counts were collected from the storm drain in 2005. The advisories occurred with the samples from the middle of the swimming area (206) and the westernmost samples (207). Isolates of human origin were found at both of these sites, with the larger numbers (and percentage, 29.5%, Table 7) found at site 207. The advisory counts were also higher at 207 (Table 3) than at 206 (Table 2). The results from sites 206 and 207 indicate that pollution containing human isolates was entering the swimming areas from a westerly direction. There is a public boat ramp directly west of the beach (Image 2) and there is a possibility that some event occurred at the boat ramp in late June and mid-August that resulted in the two beach advisories for Huntington Beach in 2006.

Table 1. Monitoring results for Huntington 205.

Collection Date	Location	OB	Tidal Level	cfu/100ml
0606A*	Huntington 205	38	Low-in	<10
0606B	Huntington 205	26	Mid-in	48
0706A	Huntington 205	46	Low-out	<10
0706B	Huntington 205	34	High-in	<10
0806A	Huntington 205	39	High-out	17
0806B	Huntington 205	42	Low-in	63

*Sample A collected 2nd week and sample B collected 4th week of each month.

Table 2. Monitoring results for Huntington 206.

Collection Date	Location	OB	Tidal Level	cfu/100ml
0606A*	Huntington 206	42	Low-in	14
0606B	Huntington 206	31	Mid-in	53
0706A	Huntington 206	40	Low-out	31
0706B	Huntington 206	56	High-in	12
0806A	Huntington 206	34	High-out	28
0806B	Huntington 206	37	Low-in	75
VDH** 6/28	Huntington 206	52		**362**
VDH 6/29	Huntington 206	39		**217**
VDH 8/17	Huntington 206	44		**143**

*Sample A collected 2nd week and sample B collected 4th week of each month.
**Samples provided by VDH during advisories.

Table 3. Monitoring results for Huntington 207.

Collection Date	Location	OB	Tidal Level	cfu/100ml
0606A*	Huntington 207	57	Low-in	<10
0606B	Huntington 207	45	Mid-in	69
0706A	Huntington 207	72	Low-out	21
0706B	Huntington 207	30	High-in	15
0706A	Huntington 207	64	High-out	42
0706B	Huntington 207	25	Low-in	84
VDH** 6/28	Huntington 207	71		**854**
VDH 6/29	Huntington 207	62		**531**
VDH 8/17	Huntington 207	65		**220**

*Sample A collected 2nd week and sample B collected 4th week of each month.
**Samples provided by VDH during advisories.

Table 4. Monitoring results for Huntington SW.

Collection Date	Location**	OB	Tidal Level	cfu/100ml
0606A*	Huntington SW	37	Low-in	45
0606B	Huntington SW	45	Mid-in	73
0706A	Huntington SW	72	Low-out	64
0706B	Huntington SW	32	High-in	29
0706A	Huntington SW	64	High-out	42
0706B	Huntington SW	35	Low-in	67

*Sample A collected 2nd week and sample B collected 4th week of each month.
**Huntington SW collected from the storm drain outfall.

Table 5. Microbial source tracking results for Huntington 205.

Collection Date	Location	Bird	Human	Dogs	Wildlife	Total
0606A*	Huntington 205	0	0	0	0	0
0606B	Huntington 205	16	0	2	6	24
0706A	Huntington 205	0	0	0	0	0
0706B	Huntington 205	0	0	0	0	0
0806A	Huntington 205	9	0	6	1	16
0806B	Huntington 205	14	0	7	3	24
Total	Huntington 205	**39**	**0**	**15**	**10**	**64**
%		**60.9**	**0.0**	**23.4**	**15.7**	**100**

*Sample A collected 2nd week and sample B collected 4th week of each month.

Table 6. Microbial source tracking results for Huntington 206.

Collection Date	Location	Bird	Human	Dogs	Wildlife	Total
0606A*	Huntington 206	8	0	1	1	10
0606B	Huntington 206	11	3	0	2	16
0706A	Huntington 206	14	1	0	1	16
0706B	Huntington 206	7	0	2	1	10
0806A	Huntington 206	13	0	1	2	16
0806B	Huntington 206	9	2	2	3	16
VDH** 6/28	Huntington 206	15	5	3	1	24
VDH 6/29	Huntington 206	14	7	0	3	24
VDH 8/17	Huntington 206	13	6	2	3	24
Total	Huntington 206	**104**	**24**	**11**	**17**	**156**
%		**66.7**	**15.4**	**7.1**	**10.8**	**100**

*Sample A collected 2nd week and sample B collected 4th week of each month.
**Samples provided by VDH during advisories.

Table 7. Microbial source tracking results for Huntington 207.

Collection Date	Location	Bird	Human	Dogs	Wildlife	Total
0606A*	Huntington 207	0	0	0	0	0
0606B	Huntington 207	6	7	2	1	16
0706A	Huntington 207	10	2	1	3	16
0706B	Huntington 207	8	0	2	0	10
0806A	Huntington 207	10	0	5	1	16
0806B	Huntington 207	8	6	2	0	16
VDH** 6/28	Huntington 207	11	8	3	2	24
VDH 6/29	Huntington 207	12	11	1	0	24
VDH 8/17	Huntington 207	10	9	3	2	24
Total	Huntington 207	**75**	**43**	**19**	**9**	**146**
%		**51.4**	**29.5**	**13.0**	**6.1**	**100**

*Sample A collected 2nd week and sample B collected 4th week of each month.
**Samples provided by VDH during advisories.

Table 8. Microbial source tracking results for Huntington SW.

Collection Date	Location*	Bird	Human	Dogs	Wildlife	Total
0606A**	Huntington SW	11	0	3	2	16
0606B	Huntington SW	12	0	1	3	16
0706A	Huntington SW	11	0	2	3	16
0706B	Huntington SW	13	0	3	0	16
0806A	Huntington SW	10	0	4	2	16
0806B	Huntington SW	9	0	4	3	16
Total	Huntington SW	**66**	**0**	**17**	**13**	**96**
%		**68.8**	**0.0**	**17.7**	**13.5**	**100**

*Huntington SW collected from the storm drain outfall.
**Sample A collected 2nd week and sample B collected 4th week of each month.

The storm drain was not a problem at Huntington Beach in 2006, as the *Enterococcus* counts were low and fluorometry results (detection of optical brighteners [OB] from detergents) were negative (below 100, Table 4). All fluorometry results were low from all sites in 2006 (Tables 1-4). The presence of human isolates in both the VT and advisory samples at 206 and 207 (Tables 6 and 7), accompanied by low OB values (Tables 2 and 3), indicated that the human isolates were from neither storm drains nor sewers. Dumping human wastes into the water by boaters around the public boat ramp is a possible source, as such wastes would not be expected to contain laundry detergents, explaining why the OB values were low and the advisory counts were high at 206 and higher at 207 (and increased from 206 to 207, in the direction of the boat ramp, Tables 2 and 3).

Plans for Huntington Beach in 2007

Sampling by the VT staff will concentrate on the waters around the boat ramp and the western end of the swimming area, where the high counts but no evidence of optical brighteners were found. The boat ramp is upstream from the swimming area and this may have helped pollution from the boat ramp area move into the swimming zone. Samplings in 2007 will be coordinated again with the VDH staff so that additional collections can be made (by either VDH or VT staff) whenever advisories are posted in an attempt to relate advisories to certain conditions or events such as tides, storms, wind direction, and bird patterns. This may help explain the origins of the high *Enterococcus* counts that might result in sporadic advisories at this beach. Careful attention to the activities of boaters to prevent waste dumping in the water should help Huntington Beach hopefully remain clear of advisories in 2007, as it did in 2005.

Figure 1. Huntington Beach, the swimming area (within the buoys) can be seen past the lifeguard station. Site 205 is to the left and site 206 is to the right of the large sign.


Figure 2. Site 207 is within the swimming area to the left, near the buoys, and the public boat ramp can be seen past the swimming area (upriver).

1. E. Yorktown Beach

Yorktown Beach is a small beach located on the south bank of the York River immediately southeast of the George P. Coleman Memorial Bridge. The beach consists of two adjacent swimming areas, separated by sand and retained by a small break-wall, and with the easternmost pool enclosed by buoys. The Peninsula Health District monitors this beach and samples weekly at two locations, one in each swimming area. Yorktown Beach had no swimming advisories in 2004, 2005 or 2006, and contains no visible storm drains in or around the beach area. The appearance of this beach is very clean, and the Village of Yorktown provides a high level of maintenance at this beach. The beach is popular and is routinely used by swimmers. No dog wastes were ever observed on this beach. In addition to the weekly VDH monitoring in 2006, VT staff collected three sets of samples from this beach following precipitation events to determine if storms or rainfall impacted water quality. In Table 1, Yorktown A was taken at the VDH sampling site in the western swimming area and Yorktown B was collected at the VDH sampling site in the eastern swimming area. All monitoring results were well below the regulatory standard (Table 1), and source tracking results from the three samplings in August showed a dominant bird and a smaller wildlife signature at both locations. No isolates from dogs or humans were detected, and fluorometry readings for optical brighteners (OB) were all negative (below 100), indicating that the water at this beach was in good condition when the samples were collected following precipitation events in June, July, and August, 2006 (see images on following page).

Table 1. Monitoring and source tracking results for Yorktown Beach in 2006.

Date	Beach/Location	Bird	Human	Dog	Wildlife	Total	cfu/100ml	OB (mg/l)
06/22	Yorktown A	10	0	0	2	12	17	31
	Yorktown B	9	0	0	3	12	24	27
07/12	Yorktown A	10	0	0	2	12	31	42
	Yorktown B	12	0	0	0	12	14	36
08/17	Yorktown A	11	0	0	1	12	36	29
	Yorktown B	8	0	0	4	12	42	41

Plans for Yorktown Beach in 2007

Yorktown had no problems or advisories in 2004, 2005 or 2006, and no visible means by which bacteria could be transported in large numbers into the swimming area from locations off the beachfront. The sampling in 2006 indicated that precipitation events did not negatively impact water quality. No monitoring at this beach, other than what is planned by VDH staff, will be needed in 2007 unless advisories occur.

Image 1. The western swimming area at Yorktown Beach.

Image 2. The eastern swimming area at Yorktown Beach.

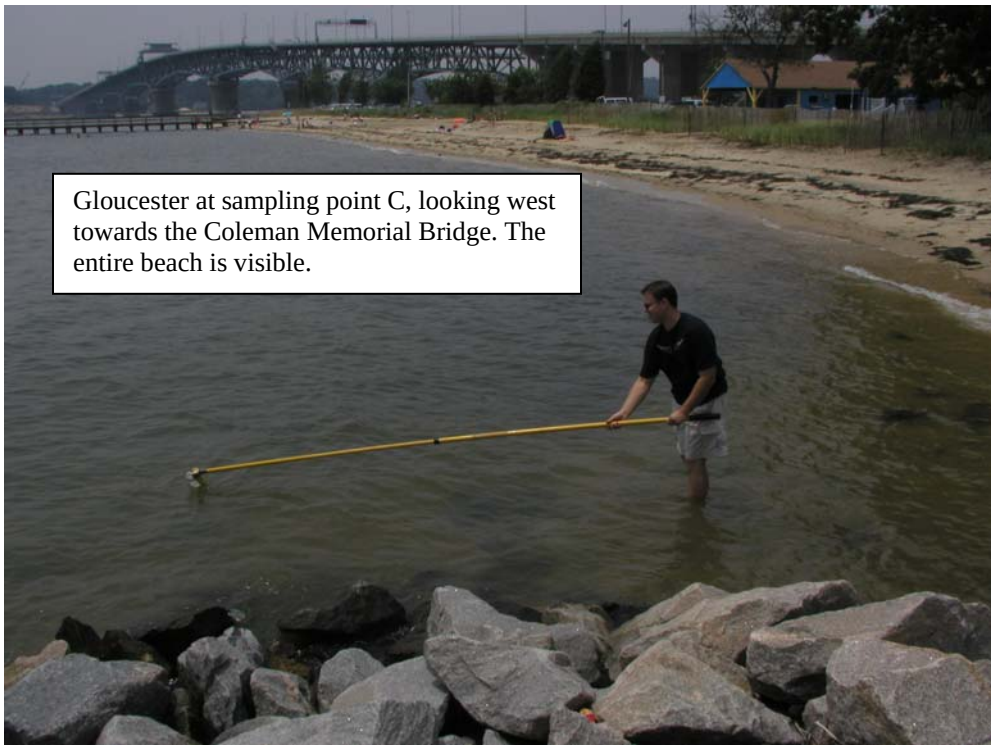
2. Three Rivers Health District

2. A. Gloucester Point Beach

Gloucester Point Beach is a small beach located on the north bank of the York River just east of the George P. Coleman Memorial Bridge and adjacent to the Virginia Institute of Marine Sciences (VIMS). Gloucester Point Beach is no more than 200 yards long and contains a well-maintained, lighted wooden fishing/recreation pier in the middle section of the beach (see picture below). The Three Rivers Health District monitors this beach and samples at two locations. There was one swimming advisory that lasted one day in 2004, and there were no advisories in 2005 or 2006. The beach is well-maintained, trash receptacles are provided, and dogs are not permitted on the beach. This is a popular local beach and swimmers use it routinely, especially on weekends.

Fishing pier at Gloucester Point Beach.

In addition to the weekly VDH monitoring in 2006, VT staff collected three sets of samples from this beach following precipitation events to determine if storms or rainfall impacted water quality. In Table 1, Gloucester A was taken about 50 feet to the west of the pier, within the main swimming area. Gloucester B was collected from the end of the pier, and Gloucester C was collected at the northeastern end of the swimming area along a rock barrier adjacent to VIMS property (see picture on following page). All monitoring results were well below the regulatory standard (Table 1), and source tracking results from the three samplings showed a dominant bird and a smaller wildlife signature at all three locations. No isolates from dogs or humans were detected, and fluorometry readings for optical brighteners (OB) were all negative (below 100), indicating that the water at this beach was in good condition when the samples were collected following precipitation events in June, July, and August, 2006.



Gloucester at sampling point C, looking west towards the Coleman Memorial Bridge. The entire beach is visible.

No storm drains or other structures are visible anywhere along Gloucester Point to contribute to *Enterococcus* counts, and with regular trash collection, large numbers of birds have not been attracted to the fishing pier.

Table 1. Monitoring and source tracking results for Gloucester Point Beach in 2006.

Date	Beach/Location	Bird	Human	Dog	Wildlife	Total	cfu/100ml	OB (mg/l)
06/22	Gloucester A	6	0	0	6	12	17	41
	Gloucester B	8	0	0	4	12	25	36
	Gloucester C	12	0	0	0	12	31	32
07/12	Gloucester A	9	0	0	3	12	27	40
	Gloucester B	6	0	0	6	12	45	27
	Gloucester C	8	0	0	4	12	42	34
08/17	Gloucester A	7	0	0	5	12	36	28
	Gloucester B	10	0	0	2	12	51	47
	Gloucester C	8	0	0	4	12	29	31

Plans for Gloucester Point Beach 2007

Gloucester Point Beach had no problems or advisories in 2005 or 2006, and no visible means by which bacteria could be transported in large numbers into the swimming area from locations off the beachfront. The sampling in 2006 indicated that precipitation events did not negatively impact water quality. No monitoring at this beach, other than what is planned by VDH staff, will be needed in 2007 unless advisories occur.

6. Rappahannock Health District

6. A. Fairview Beach

Fairview Beach is located on the southern bank of the Potomac River, northeast of Fredericksburg. The Rappahannock Health District monitored 3 sites weekly across the length of the beach (roughly 1 mile of shoreline) during the swimming season (the designated swimming area where two of the samples are collected is only a 75-100 yards long). Fairview Beach posted four swimming advisories during the summer of 2004, three advisories in 2005 and three advisories in 2006. All three 2006 advisories covered several days and totaled some 33 days under advisory. Fairview Beach sustained heavy damage from Hurricane Isabel in 2003, substantial beach restoration was done in 2005, then tropical storm Ernesto wrecked the beach again on September 1 and 2, 2006. Heavy winds and high tides created waves that washed over the concrete bulkheads that were seen by VT staff on a July trip to Fairview (image 4), and many of the sections of the bulkhead were dislodged and washed into the river. The beach is popular in the summer, especially on weekends. Fairview Beach is currently not in good condition after the September 2006 storm. An additional ten to fifteen yards of beach is needed, at a minimum, as over half of the remaining beach is submerged at high tide. Trash on the beach does not appear to be much of a problem, but dogs are not restricted and pet wastes were observed near the beach on sampling trips in 2004 and 2005 and 2006 (an indication of little progress with dogs). The area surrounding the beach also needs improvement in drainage control so that precipitation does not flow down the steep bluffs adjacent to the beach and then directly into the swimming areas. Finally, breakwater structures need to be repaired to control beach erosion from tides and storms. Without such improvements, periodic swimming advisories should be expected in the future, especially in wet summers.

From May through July, 2005, samples from Fairview Beach collected by VDH staff were taken to the DSS-VDH lab in White Stone, VA. From August to mid-September 2005 and during 2006 water samples were sent by courier or hand delivered by VDH staff to the state lab in Richmond, the Division of Consolidated Laboratory Services (DCLS). Both labs used a membrane-filtration technique to obtain the *Enterococcus* counts on the weekly samples. All filtration plates that contained sufficient colonies for source tracking to be performed (greater than 10 CFU/100 mL) were sent to the VT lab, including those plates where the counts exceeded the standard and a swimming advisory was posted. Additional samples were taken in June and July, 2006, by the VT staff from sites around the regular sampling locations. In 2004 a sinkhole located at 8th Street was found and sampled. A strong human signature was obtained from the source tracking results and fluorescent compounds were detected that were consistently double the concentration found in the open waters of the Potomac River, validating the result that human isolates were detected by source tracking. The 8th St. sinkhole was filled in with concrete at the end of 2004. Sampling at this location in 2005 resulted in low counts and no isolates of human origin, so sampling at this site (VDH Site 2) was discontinued in 2006 (this location was not a swimming area).

In 2006, VDH staff collected 18 samples from each of three locations, and only 14 (25.9%) of 54 total samples produced counts below 10 CFU/100 mL. Twenty-one (38.9%) of the 54 samples exceeded the regulatory standard, a clear indication of the poor water quality conditions in the Potomac River at Fairview Beach in 2006. For the three following tables, the monitoring results were performed by the DCLS lab and the plates were sent to VT for source tracking. There were no optical brightener results for these samples as plates were sent to VT, not water samples.

Table 1. Source tracking results for VDH sampling site 1.

Date	Counts-CFU/100mL	Birds	Humans	Dogs	Wildlife	Total
6/5/2006	54	12	0	4	0	16
6/12/2006	150	8	2	4	2	16
6/15/2006	360	6	4	5	1	16
6/26/2006	280	8	3	4	1	16
6/29/2006	140	13	0	3	0	16
7/5/2006	530	6	4	4	2	16
7/10/2006	38	12	0	3	1	16
7/24/2006	52	12	0	2	2	16
8/7/2006	53	9	0	3	4	16
8/26/2006	30	13	0	0	3	16
9/5/2006	>800	4	9	3	0	16
9/11/2006	140	5	6	3	2	16
2006	**Totals**	**108**	**28**	**38**	**18**	**192**
2006	**Percentages**	**56.2**	**14.6**	**19.8**	**9.4**	**100**

Table 2. Source tracking results for VDH sampling site 3.

Date	Counts-CFU/100mL	Birds	Humans	Dogs	Wildlife	Total
6/5/2006	54	12	0	2	2	16
6/12/2006	220	8	5	5	1	16
6/15/2006	260	6	4	4	1	16
6/26/2006	2,300	8	8	5	0	16
6/29/2006	88	0	0	1	1	16
7/5/2006	160	3	4	3	3	16
7/10/2006	44	13	0	0	2	16
7/24/2006	4	0	0	0	0	0
8/7/2006	20	9	0	0	4	16
8/26/2006	50	13	0	2	3	16
9/5/2006	>800	4	7	5	2	16
9/11/2006	96	3	3	1	2	16
2006	**Totals**	**96**	**31**	**28**	**21**	**176**
2006	**Percentages**	**54.6**	**17.6**	**15.9**	**11.9**	**100**

For VDH sampling site 1, seven of twelve samples (58%) exceeded the standard (Table 1). The major sources of the *Enterococcus* isolates were birds (56.2%), with dogs, humans, and wildlife, as secondary sources (19.8%, 14.6%, and 9.4%, respectively, Table 1). Human isolates were found in six of the twelve samples and the percent human (14.6%) was sufficiently high to allow confidence that this was a "real" signature. For VDH sampling site 3, five of eleven samples (45.4%) exceeded the standard (Table 2). The major sources of the *Enterococcus* isolates were birds (54.6%), with humans, dogs, and wildlife, as secondary sources (17.6%, 15.9%, and 11.9%,

respectively, Table 2). Human isolates were found in six of the eleven samples and the percent human (17.6%) was sufficiently high to allow confidence that this was a "real" signature. The largest single count (2,300) of all samples was obtained at this site on 6/26/2006 (Table 2). For VDH sampling site 4, eight of eleven samples (72.7%) exceeded the standard (Table 3). The major sources of the *Enterococcus* isolates were birds (58.5%), with humans, dogs, and wildlife, as secondary sources (14.8%, 13.6%, and 13.1%, respectively, Table 3). Human isolates were found in six of the eleven samples and the percent human (14.8%) was sufficiently high to allow confidence that this was a "real" signature. The results from tables 1-3 demonstrate high counts and evidence of pollution from humans and dogs at all locations, especially in June. Such results show the poor water quality conditions that were present at Fairview Beach over much of the 2006 swimming season.

At first glance it might appear that birds were the main problem at Fairview in 2006. This would be misleading. While birds represented the greatest proportion of isolates when counts were low (for example, birds were 14 of 16 isolates on 6/12 with 120 CFU/100 mL and 7/24 with 32 CFU/100 mL, Table 3), birds represented much smaller proportions when counts were high (for example, 5 of 16 isolates on 6/26 with 1,200 CFU/100 mL and 2 of 16 isolates on 9/5 with >800 CFU/100 mL, Table 3). When only the high counts that were responsible for most of the advisories are examined in Tables 1-3, humans and dogs typically added up to a much larger proportion (and greater problem) than birds.

Table 3. Source tracking results for VDH sampling site 4.

Date	Counts-CFU/100mL	Birds	Humans	Dogs	Wildlife	Total
6/5/2006	120	11	1	2	2	16
6/12/2006	120	14	0	1	1	16
6/15/2006	260	9	2	2	3	16
6/26/2006	1,200	5	6	5	0	16
6/29/2006	126	12	0	2	2	16
7/5/2006	300	9	4	2	1	16
7/10/2006	34	13	0	0	3	16
7/24/2006	32	14	0	1	1	16
8/7/2006	76	10	0	2	4	16
8/26/2006	6	0	0	0	0	0
9/5/2006	>800	2	8	6	0	16
9/11/2006	200	7	5	2	2	16
2006	**Totals**	**103**	**26**	**24**	**23**	**176**
2006	**Percentages**	**58.5**	**14.8**	**13.6**	**13.1**	**100**

The VT staff sampled Fairview Beach on 6/23 and 7/13 to evaluate the beach in more detail (Tables 4 and 5). VDH sampled on 6/20 and 6/26. Examining the VDH on-line records indicates that the counts were very low on 6/20 and there was no advisory, while the VDH counts on 6/26 were the highest recorded for any beach during the 2006 season (at sites 3 and 4, see Tables 2 and 3). Clearly something substantial happened between these two dates; there was a substantial rainfall event, on 6/21-6/22, and this is a possibility as there is no other direct evidence to indicate what happened to cause such pollution on 6/26, only seven days after very low counts were recorded on 6/20. The VT results from 6/23 (Table 4) were in-between the VDH counts on

6/20 and 6/26, but were all above the regulatory standard and would have resulted in an advisory if VDH had sampled on 6/23 (VDH Sites 1, 3, and 4, Table 4).

Table 4. Monitoring and source tracking results for Fairview Beach on 6/23/2006.

Location	CFU/100mL	Birds	Humans	Dogs	Wildlife	Total	OBs
VDH Site 1	214	8	2	4	2	16	64
VDH Site 3	465	5	3	5	3	16	95
VDH Site 4	318	7	3	5	1	16	70
Storm drain	158	6	5	4	1	16	112
Sand at storm drain	180	5	6	4	1	16	---
25m out, Site 1	90	13	0	1	2	16	54
25m out, Site 3	175	12	1	2	1	16	67
25m out, Site 4	140	11	1	2	2	16	46
2006	**Totals**	**67**	**21**	**27**	**13**	**128**	---
2006	**%**	**52.3**	**16.4**	**21.1**	**10.2**	**100**	---

The optical brightener (OB) readings for site 3 and the storm drain (images 1 and 2) were positive (or were close, a positive is a reading of 100 or above). The counts and OB readings that were taken 25m further out at each VDH site were lower than those taken at the three sites, indicating that the pollution appeared to be coming from the shore as the weaker OB readings and lower counts were obtained further away from the shore. The major sources of the *Enterococcus* isolates were birds (52.3%), with dogs, humans, and wildlife, as secondary sources (21.1%, 16.4%, and 10.2%, respectively, Table 4). Human isolates were found in seven of the eight samples and the percent human (16.4%) was sufficiently high to allow confidence that this was a "real" signature. There were greater numbers of human and dog isolates recovered from the VDH sites, the storm drain, and the sand at the mouth of the storm drain, than at the sites 25m out, where the major source of isolates was birds rather than humans and dogs (Table 4).

Table 5. Monitoring and source tracking results for Fairview Beach on 7/13/2006.

Location	CFU/100mL	Birds	Humans	Dogs	Wildlife	Total	OBs
VDH Site 1	195	6	6	3	1	16	68
VDH Site 3	155	8	2	4	2	16	66
VDH Site 4	220	6	5	3	2	16	70
Storm drain	560	7	6	3	0	16	119
Water and sand at right of storm drain	540	1	9	4	2	16	113
Water and sand at left of a storm drain	195	2	8	4	2	16	121
Creek drainage	1,780	1	7	5	3	16	149
25m out, Site 1	65	10	2	2	2	16	53
25m out, Site 3	73	13	0	2	1	16	45
25m out, Site 4	50	13	1	1	1	16	47
2006	**Totals**	**67**	**46**	**31**	**16**	**160**	---
2006	**%**	**41.9**	**28.8**	**19.3**	**10.0**	**100**	---

Additional samples were collected on 7/13, also after a substantial precipitation event had occurred within two days previous to the sampling trip (Table 5). VDH sampled on 7/10 and 7/17. Examining the VDH on-line records indicates that the counts were moderately low on both dates and there was no advisory (see 7/10 date in Tables 1, 2, and 3). The VT results from 7/13 (Table 5) were all above the regulatory standard and would have resulted in an advisory if VDH had sampled on 7/13 (VDH Sites 1, 3, and 4, Table 5). It is possible that the rainfall event on 7/11-7/12 resulted in the high counts that were obtained by the VT staff on 7/13, but these higher counts had dissipated by 7/17 when VDH next sampled. The optical brightener (OB) readings for the storm drain (images 1 and 2), the creek drainage, and the water at the left and right of the end of the storm drain were positive (a positive is a reading of 100 or above). The counts and OB readings that were taken 25m further out at each VDH site were lower than those taken at the three sites, indicating that the pollution appeared to be coming from the shore as the weaker OB readings and lower counts were obtained further away from the shore (Table 5). This was the same trend that was observed on 6/23 (Table 4). The major sources of the *Enterococcus* isolates were birds (41.9%), with humans, dogs, and wildlife, as secondary sources (28.8%, 19.3%, and 10.0%, respectively, Table 5). Human isolates were found in nine of the ten samples and the percent human (28.8%) was sufficiently high to allow confidence that this was a "real" signature. There were greater numbers of human and dog isolates recovered from the VDH sites, the storm drain, the creek drainage, and the sand at the mouth of the storm drain, than at the sites 25m out, where the major source of isolates was birds rather than humans and dogs (Table 5).

Plans for Fairview Beach in 2007.

Based on 2004 through 2006 results, birds, dogs, wildlife and human sources are all potential contributors at Fairview Beach. The persistent human signatures at all three VDH sampling locations are especially problematic, and efforts to determine the sources of it will be a focus of research at Fairview Beach in 2007. It appears that precipitation is the cause of many of the problems at Fairview Beach, and the storm drain needs to be dealt with as part of any long-term solution to improve water quality at Fairview Beach. Additional plans for rebuilding have been developed after the erosion caused by Ernesto in September. It is not known if these projected repairs will be done in 2007 or not. For any advisories that occur in 2007, source tracking will be performed as rapidly as possible and, if human-origin isolates are found, then an immediate follow-up trip will occur so that intensive sampling can be performed in an effort to locate the sources of the human-origin pollution with a combination of source tracking and fluorometry. Filter plates will continue to be sent to the VT lab from the DCLS lab so that source tracking can be performed on the weekly samples as needed.

Image 1. Restaurant and drainage pipe adjacent to the swimming area at Fairview Beach (see image 5). The swimming area is behind the photographer.

Image 2. Sampling the drainage pipe at Fairview Beach.

Image 3. Area to the west of the restaurant showing erosion and drainage from the land that could impact the swimming area on the other side of the restaurant.

Image 4. Upriver shore-line improvements, with the restaurant in the background. Tropical storm Ernesto washed several of the concrete wall blocks into the water on September1 and 2, 2006.

Image 5. Swimming area at Fairview Beach (inside the buoys to the left). The restaurant and drainage pipe are behind the photographer.

3. Hampton City Department of Health

3. A. Buckroe Beach and Related Locations

The Hampton City Department of Health monitors four beach sites along the western shore of the Chesapeake Bay. Samples were collected weekly by VDH staff for the 2004, 2005, and 2006 beach seasons from Buckroe Beach at three locations (North-, Mid- and South-Buckroe), and one sample is collected at Salt Ponds near the First Street entrance (roughly 1 mile north of Buckroe Beach). Sample collection from Grandview Pier, one mile north of Salt Ponds, was discontinued after the July 7 sample.. The fishing piers at Buckroe Beach and Grandview Pier were wrecked by Hurricane Isabel in 2003. The Grandview pier had not been repaired by the summer of 2006; rebuilding was started on the Buckroe pier in 2006 but it was not open to the public in the 2006 swimming season. All of the beaches also suffered hurricane damage, but most of the planned beach restoration had been completed by the 2005 swimming season. Buckroe is heavily used by swimmers, while North Buckroe, Salt Ponds and Grandview much less so, and public access is limited to all but Buckroe Beach. There were two swimming advisories at Buckroe Beach in 2004, one at North Buckroe, and none at Salt Pond or Grandview in 2004. There were no swimming advisories in 2005 or 2006 for any of the beaches.

There were two storm drains that emptied into the swimming areas at Buckroe Beach, and these were sampled regularly through manhole access by the VT staff in 2004. The drains almost always contained liquid, even when no rainfall had occurred, and samples sporadically yielded high *Enterococcus* counts and were positive for optical brighteners. It was never possible to determine exactly where the water in the drains was coming from, so city engineers improved drainage around both storm drains to reduce water seeping into the drains, both storm drains were extended over 100 yards further out into the bay, and the beach was rebuilt and another 50 to 60 yards of beach was added and extended further out. All of these improvements were completed by the 2005 swimming season and had a positive outcome, no swimming advisories in 2005 and 2006. There was rarely any water in the storm drains when they were inspected by the VT staff in 2005 and 2006 when samples were collected from the swimming areas.

Samples were collected regularly over the summer of 2006 at Buckroe Beach by VT staff at three locations; sampling site A was 100 yards south of the condemned pier (where one of the storm drains had been extended), sampling site B was adjacent to the condemned pier (on the south side), and sampling site C was 100 yards north of the condemned pier, where the second storm drain had been extended. All samples were collected approximately 20 to 30 yards from the beach, where the water was knee to waist deep. For the tables on the following pages, the date followed by an "A" (for example, 0606A) indicates that the sample was collected in June, 2006, on the second week of each month (A), June thru August, and the date followed by a "B" indicates the sample was collected the fourth week of each month.

For all three sampling sites there were no counts that exceeded the standard, and all optical brightener readings were negative (Tables 1-3). Samples were collected frequently enough so that a variety of tidal conditions were encountered, and there was no relationship between the tide and the *Enterococcus* counts. The extension of the beach created what is essentially a very large sand filter. The sand at a beach can serve as a filter and remove many of the pollutants and bacteria that would otherwise find their way into the water. Since large numbers of shore birds and nuisance birds (pigeons) were frequently seen on or near the beach, and there were no advisories in 2005 and 2006, the beach improvements are clearly having a positive impact in serving as a sand filter, even though that was not the intention of the rebuilding efforts. The other beaches were not sampled on a regular basis because they are seldom used for swimming and there had only been one swimming advisory (North Buckroe) in 2004, none in 2005 or 2006.

Other than June, all counts for July and August were less than 10 CFU/100 mL for all three sites (Tables 1-3), so source tracking was not performed on these samples with low counts. All optical brightener results from the three sites were negative as well (below 100).

Table 1. Monitoring data for Buckroe Beach, site A.

Collection Date	Location*	Optical Brighteners	Tidal Level	cfu/100mL
0606A**	Buckroe A	35	Low-out	14
0606B	Buckroe A	32	Low-out	37
0706A	Buckroe A	37	Low-out	<10
0706B	Buckroe A	28	Mid-out	<10
0806A	Buckroe A	26	High-out	<10
0806B	Buckroe A	21	High -in	<10

*Buckroe A collected 100 yards south of the pier.
**A collected 2^{snd} week and B collected 4th week of each month.

Table 2. Monitoring data for Buckroe Beach, site B

Collection Date	Location*	Optical Brightener	Tidal Level	cfu/100mL
0606A**	Buckroe B	27	Low-out	33
0606B	Buckroe B	41	Low-out	42
0706A	Buckroe B	32	Low-out	<10
0706B	Buckroe B	46	Mid-out	<10
0806A	Buckroe B	30	High-out	<10
0806B	Buckroe B	24	High -in	<10

*Buckroe B collected adjacent to the pier, on the south side.
**A collected 2snd week and B collected 4th week of each month.

Table 3. Monitoring data for Buckroe Beach, site C.

Collection Date	Location*	Optical Brightener	Tidal Level	cfu/100mL
0606A**	Buckroe C	33	Low-out	27
0606B	Buckroe C	54	Low-out	33
0706A	Buckroe C	41	Low-out	<10
0706B	Buckroe C	34	Mid-out	<10
0806A	Buckroe C	35	High-out	<10
0806B	Buckroe C	26	High -in	<10

*Buckroe C collected 100 yards north of the pier.
**A collected 2snd week and B collected 4th week of each month.

Microbial Source Tracking (MST) results showed birds as the dominant signature (75.5%, Table 4), with some minor contribution from dogs (9.6%) and wildlife (14.9%, Table 4). The 6 biweekly samplings were combined for each of the three sites since the results were nearly the same for all samples. No human-origin isolates were detected from any of the samples and it appears that alterations to the storm drain system and rebuilding plus extending the beach have eliminated the human-origin pollution that was detected on occasion in 2004. There is now an area at Buckroe Beach set aside for exercising and walking dogs, and the absence of advisories in 2005 and 2006 indicates that the beach replenishment and drainage changes that were made prior to the 2005 swimming season were effective.

Table 4. Source tracking results for Buckroe Beach, all dates combined.

Date	Beach/Location	Birds	Humans	Dogs	Wildlife	Total
6/2006	Buckroe A	22	0	3	5	30
6/2006	Buckroe B	26	0	2	4	32
6/2006	Buckroe C	23	0	4	5	32
6/2006	Totals	71	0	9	14	94
6/2006	Percentages	75.5	0	9.6	14.9	100

Plans for Buckroe and Related Beaches in 2007

There is little need to continue regular sample collections by the VT staff at North Buckroe, Salt Ponds, or Grandview. While the public is not prohibited from using these beaches, there is no public parking and no signs identifying public access. It is debatable as to whether or not these are truly public beaches. With the changes made to Buckroe Beach in 2005, further advisories are unlikely. The only possibilities are the potential attraction of shore birds to the pier, but there are already large flocks of birds in the area and these were not a problem in 2005 or 2006. No monitoring at this beach, other than what is planned by VDH staff, will be needed in 2007 unless advisories occur.

The images below illustrate current conditions at Buckroe Beach. Image 1 shows the condemned pier in 2005 and image 2 shows the pier in 2004. By comparing the two images, the size of the beach extension can readily be seen as much of the pier in image 1 is now over sand instead of water. Plans are underway to rebuild the pier, but construction was halted in 2005 and 2006 by the discovery of nesting shorebirds that were identified as endangered (image 4). Officials plan on having the pier rebuilt and open for the 2007 swimming season, and construction of the new pier is now underway. A "Bark Park" (image 3) was added in 2005 as a place to walk and exercise dogs and to encourage pet owners to not take their pets on the beach. Receptacles for pet wastes are provided at the park. This has helped lower the source tracking results attributed to dogs from 2004 through 2006 (9.6% in 2006, Table 4).

Image 1. Rebuilt and extended beach, and condemned pier, in 2005.

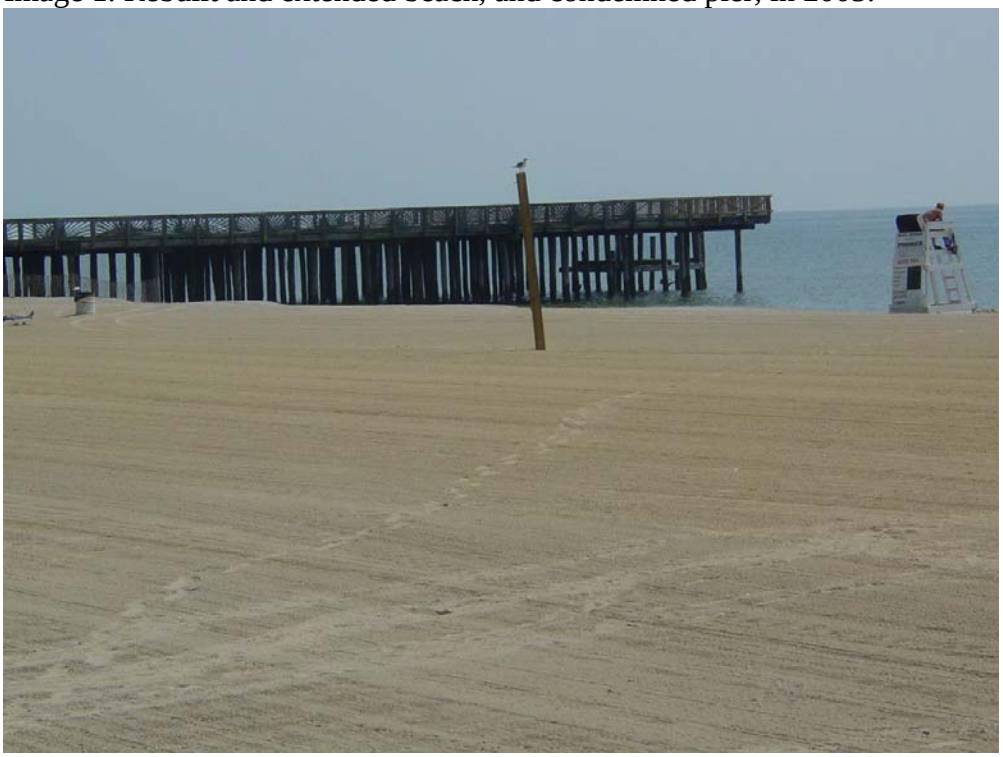


Image 2. Beach and condemned pier in 2004.

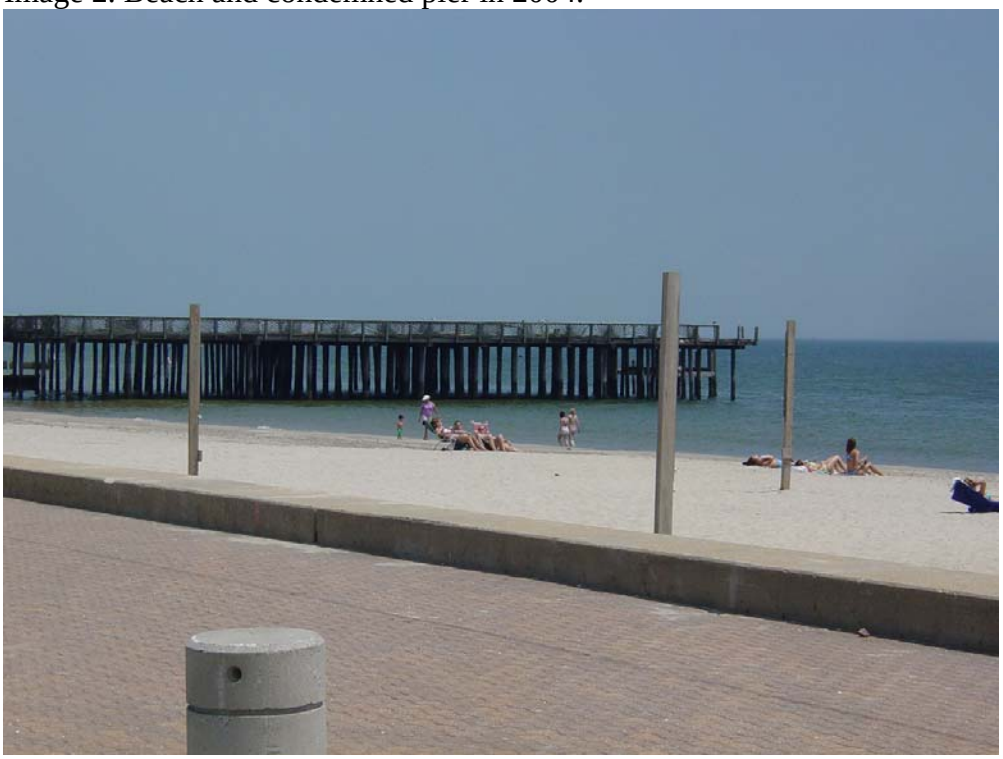


Image 3. Area provided for walking and exercising dogs, 2005 and 2006.

Image 4. Nesting birds halted reconstruction of the pier in summers of 2005 and 2006.

4. Norfolk Department of Health

4. A. Norfolk Beaches

Norfolk beaches encompass a five-mile stretch along the southern side of the Chesapeake Bay between the Norfolk Naval Station and US Navy Little Creek Amphibious Base. The Norfolk Health Department monitored nine locations weekly during the 2004 and 2005 beach seasons. There were two swimming advisories in 2004, none in 2005, and none in 2006. The Norfolk beaches were heavily damaged, and two piers were destroyed, by Hurricane Isabel in September, 2003. Major beach restoration efforts were underway throughout the summer of 2004 and into 2005 that included dredging sand to increase the width of the beaches, installing breakwaters to reduce beach erosion, and repairing or constructing jetties to further protect the beaches. Appropriate vegetation was planted on the upper portions of several beaches to stabilize the sand and protect sand dunes, and a very large pier was under construction during the summer of 2005 (opened to the public in 2006). The Norfolk beaches are also the recipient of fortunate geography. The main currents that move in and out of the lower bay and the ocean with tidal changes run along the Norfolk coast. These currents help to quickly disperse and dilute any pollutants in the swimming areas and, along with the beach and shoreline restoration, should result in very infrequent swimming advisories. The success of the beach improvements was apparent in 2005 and 2006 (no advisories). There are numerous storm drain outfalls on many of the Norfolk beaches, and samples collected in 2004 from these outfalls produced *Enterococcus* counts well above state standards. Even though most of the outfalls empty directly into swimming areas, only 11 (8.1%) of the 135 weekly samples collected by the VDH staff from the Norfolk beaches in 2005 produced *Enterococcus* counts above 10 cfu/100mL (and the highest count recorded for the summer was just 85 cfu/100mL). These results demonstrate the positive impact of beach replenishment in combination with active currents that move water away from the beaches.

In 2006, as in 2005, the VT staff concentrated on collecting samples (twice a month for three months, June through August) at specific VDH sampling locations to examine the impact of beach restoration efforts on water quality. One of the sampling sites (VDH-N9) included the storm drain outfalls that produced the highest *Enterococcus* counts in 2004 and 2005. The sites where samples were collected by the VT staff in 2006 were:

VDH-N4, at 21st Bay Street, one sampling site, samples collected at the westernmost jetty to assess the impact of beach improvements.

VDH-N9, at Ocean View Park, the most popular of the Norfolk beaches. Four sampling sites:

- N9 – east end of the beach, left side of the main jetty (a VDH site)
- SW-E at N-9, east end of the beach, right side of the double storm drain
- SW-W at N-9, east end of the beach, left side of double storm drain
- SW2 at N-9, west end of the beach, right side of the storm drain

VDH-N12, at 13th Street, one sampling site, samples collected west of the main jetty at this location.

For the tables on the following pages (monitoring and source tracking results for the above sampling sites), the date followed by an "A" (for example, 0606A) indicates that

the sample was collected in June, 2006, the second week of each month (A), June thru August, and the date followed by a "B" indicates the sample was collected the fourth week of each month. Source tracking was performed on just the samples with counts above 10 CFU/mL. A discussion of the results and plans for the Norfolk beaches in 2007 follows the tables.

Table 1. Monitoring results for Norfolk 4 (N4).

Collection Date	Location**	OB	Tidal Level	cfu/100mL
0606A*	Norfolk 4	23	High-out	<10
0606B	Norfolk 4	28	Low-out	<10
0706A	Norfolk 4	36	Low-in	<10
0706B	Norfolk 4	24	Low-out	<10
0806A	Norfolk 4	22	High-out	<10
0806B	Norfolk 4	28	High	<10

*Sample A collected 2nd week and sample B collected 4th week of each month.
**21st Bay Street, samples collected at the westernmost jetty to assess the impact of beach improvements.

Since all monitoring results were less than 10 for Norfolk 4 (Table 1), source tracking was not performed on any samples from this site in 2006.

Table 2. Monitoring results for Norfolk 9 SW-E.

Collection Date	Location**	OB	Tidal Level	cfu/100mL
0606A*	Norfolk 9 SW-E	75	Low-out	146
0606B	Norfolk 9 SW-E	97	Low-in	78
0706A	Norfolk 9 SW-E	86	Mid-out	168
0706B	Norfolk 9 SW-E	83	High-out	133
0806A	Norfolk 9 SW-E	65	High	<10
0806B	Norfolk 9 SW-E	34	High-in	<10

*Sample A collected 2nd week and sample B collected 4th week of each month.
**Ocean View Park, samples collected from the east end of the beach, right side of the double storm drain.

Table 3. Microbial source tracking results for Norfolk 9 SW-E.

Collection Date	Location	Bird	Human	Dogs	Wildlife	Total
0606A	Norfolk 9 SW-E	9	0	2	5	16
0606B	Norfolk 9 SW-E	10	0	2	4	16
0706A	Norfolk 9 SW-E	11	0	1	4	16
0706B	Norfolk 9 SW-E	12	0	2	2	16
Total	Norfolk 9 SW-E	**42**	**0**	**7**	**15**	**64**
%		**65.6**	**0.0**	**10.9**	**23.5**	**100**

Table 4. Monitoring results for Norfolk 9 (N9).

Collection Date	Location**	OB	Tidal Level	cfu/100mL
0606A*	Norfolk 9	22	Low-in	58
0606B	Norfolk 9	36	Mid-in	76
0706A	Norfolk 9	25	Low-in	<10
0706B	Norfolk 9	21	Mid-out	<10
0806A	Norfolk 9	33	Low-in	17
0806B	Norfolk 9	19	High-in	<10

*Sample A collected 2nd week and sample B collected 4th week of each month.

**Ocean View Park, samples collected from the east end of the beach, left side of the main jetty.

Table 5. Microbial source tracking results for Norfolk 9 (N9).

Collection Date	Location	Bird	Human	Dogs	Wildlife	Total
0606A	Norfolk 9	12	0	0	4	16
0606B	Norfolk 9	14	0	1	1	16
0806A	Norfolk 9	12	0	1	3	16
Total	Norfolk 9	**38**	**0**	**2**	**8**	**48**
%		**79.2**	**0.0**	**4.2**	**16.6**	**100**

Table 6. Monitoring results for Norfolk 9 SW2.

Collection Date*	Location**	OB	Tidal Level	cfu/100mL
0606A	Norfolk 9 SW2	419	High-out	650
0606B	Norfolk 9 SW2	325	Low-out	542
0706A	Norfolk 9 SW2	460	Low-in	740
0706B	Norfolk 9 SW2	328	Low-in	620
0806A	Norfolk 9 SW2	364	Low-in	830
0806B	Norfolk 9 SW2	422	High-out	710

*Sample A collected 2nd week and sample B collected 4th week of each month.

**Ocean View Park, samples collected from the west end of the beach, right side of the storm drain.

Table 7. Microbial source tracking results for Norfolk 9 SW2.

Collection Date	Location	Bird	Human	Dogs	Wildlife	Total
0606A	Norfolk 9 SW2	8	3	4	1	16
0606B	Norfolk 9 SW2	9	2	3	2	16
0706A	Norfolk 9 SW2	7	0	4	5	16
0806A	Norfolk 9 SW2	9	1	3	3	16
Total	Norfolk 9 SW2	**33**	**6**	**14**	**11**	**64**
%		**51.6**	**9.4**	**21.8**	**17.2**	**100**

Table 8. Monitoring results for Norfolk 9 SW-W.

Collection Date	Location**	OB	Tidal Level	cfu/100mL
0606A*	Norfolk 9 SW-W	27	High-out	75
0606B	Norfolk 9 SW-W	33	Low-out	27
0706A	Norfolk 9 SW-W	15	Low-in	<10
0706B	Norfolk 9 SW-W	21	Mid-out	<10
0806A	Norfolk 9 SW-W	36	High-out	<10
0806B	Norfolk 9 SW-W	18	High	<10

*Sample A collected 2nd week and sample B collected 4th week of each month.
**Ocean View Park, samples collected from the east end of the beach, left side of the double storm drain.

Table 9. Microbial source tracking results for Norfolk 9 SW-W.

Collection Date	Location	Bird	Human	Dogs	Wildlife	Total
0606A	Norfolk 9 SW-W	11	0	2	3	16
0606B	Norfolk 9 SW-W	10	0	3	3	16
Total	Norfolk 9 SW-W	**21**	**0**	**5**	**6**	**32**
%		**65.6**	**0.0**	**15.6**	**18.8**	**100**

Table 10. Monitoring results for Norfolk 12 (N12).

Collection Date	Location**	OB	Tidal Level	cfu/100mL
0606A*	Norfolk 12	45	High-out	36
0606B	Norfolk 12	26	Low-out	25
0706A	Norfolk 12	27	Low-in	<10
0706B	Norfolk 12	36	Mid-out	<10
0806A	Norfolk 12	22	High-out	<10
0806B	Norfolk 12	29	High	<10

*Sample A collected 2nd week and sample B collected 4th week of each month.
**13th Street, samples collected west of the main jetty at this location.

Table 11. Microbial source tracking results for Norfolk 12 (N12).

Collection Date	Location	Bird	Human	Dogs	Wildlife	Total
0606A	Norfolk 12	10	0	4	2	16
0606B	Norfolk 12	9	0	2	5	16
Total	Norfolk 12	**19**	**0**	**6**	**7**	**32**
%		**59.4**	**0.0**	**18.8**	**21.8**	**100**

Discussion of Sampling and Source Tracking Results for Norfolk Beaches in 2006.

For Norfolk 4 (21st Bay Street at the westernmost jetty) there were no samples that exceeded the standard (Table 1), and source tracking was not performed on any samples from this site as all monitoring results were less than 10 CFU/100 mL. For Norfolk 9 SW-E (right side of double storm drain, east end of Ocean View Beach), there were three samples that exceeded the standard (one in June and two in July, Table 2), and the major sources of the *Enterococcus* isolates were birds (65.6% of the total, Table 3), with wildlife and dogs as secondary sources (23.5% and 10.9%, respectively, Table 3. No isolates were classified as human in origin. For Norfolk 9 (jetty at east end of Ocean View Beach) there were no samples that exceeded the standard (Table 4) and only three samples provided counts above 10 CFU/100 mL. The major sources of the *Enterococcus* isolates were birds (79.2% of the total, Table 5), with wildlife and dogs as secondary sources (16.6% and 4.2%, respectively, Table 5). No isolates were classified as human in origin. For Norfolk 9 SW2 (storm drain outfall on western end of the Ocean View Beach), all six samples exceeded the standard (Table 6), and the major sources of the *Enterococcus* isolates were birds (51.6% of the total, Table 7), with humans, dogs, and wildlife as secondary sources (9.4%, 21.8%, and 17.2%, respectively, Table 7). Six isolates were classified as human in origin, and five of the six were obtained in June (Table 7). The highest counts for all of the Norfolk samples were recorded at this location, and the optical brightener readings were positive (over 100, Table 6) for all samples. This was the only location in 2006 where high optical brightener readings were obtained. Based on observations over the summer, a laundromat located near the beach on Ocean View Avenue appears to be connected to this storm drain. This would explain the high optical brightener readings and the *Enterococcus* counts (laundering of diapers, for example). This possible laundry cross-connection with a storm drain has been reported to Norfolk officials.

For Norfolk 9 SW-W (left side of double storm drain, east end of Ocean View Beach), six samples were collected (often there is no flow from this drain) and counts above 10 CFU/100 mL were obtained from just two samples (both in June, Table 8). None of the samples exceeded the standard and the major sources of the *Enterococcus* isolates for the two samples were birds (65.6% of the total, Table 9), with wildlife and dogs as secondary sources (18.8% and 15.6%, respectively, Table 9). No isolates were classified as human in origin. For Norfolk 12 (13th Street, west of the main jetty), no samples exceeded the standard, and just two samples produced counts above 10 CFU/100 mL (both in June, Table 10). The major sources of the *Enterococcus* isolates for the two samples were birds (59.4% of the total, Table 11), with wildlife and dogs as secondary sources (21.8% and 18.8%, respectively, Table11). No isolates were classified as human in origin.

In summary, the Norfolk beaches were in better condition in 2006 than in 2005, and no swimming advisories were posted. It appears that all of the beach replenishment projects have been completed, and the storm drains that the VT staff monitored in 2006, with the exception of Norfolk 9 SW2, did not produce large numbers of enterococci. Clearly the drain at SW2 is in need of attention, as a laundry appears to be connected to it, and the large numbers of enterococci that were obtained from samples of this storm drain could impact the swimming areas of Ocean View Beach in a wetter summer. Other

than this storm drain, there is little else apparent on the Norfolk beaches that might be expected to cause swimming advisories. The *Enterococcus* counts and optical brightener readings from all sites were lower in 2006 than in 2005, indicating that progress is being made in improving water quality at the Norfolk beaches.

Plans for Norfolk Beaches in 2007

The Norfolk beaches essentially started with a "clean slate" in 2005 as a result of the beach restoration efforts necessitated by Hurricane Isabel in 2003. The most visible potential sources of water pollution in 2004, as the restoration projects were underway, were birds and storm drains. People were observed walking dogs on the beach in 2004, 2005, and 2006 but individuals were also observed picking up dog wastes, so an effective education program about beach litter seems to be in place in Norfolk. Although source tracking indicated that a small percentage of the *Enterococcus* isolates at most locations were from dogs in 2005 and 2006 (see all source tracking tables), these did not result in advisories (but there is still room for improvement to further reduce contamination from dogs). Neither the storm drain at Norfolk 9 SW2 (possible cross-connection) nor the new fishing pier negatively impacted water quality in the monitored areas. No monitoring at this beach, other than what is planned by VDH staff, will be needed in 2007 unless advisories occur.

Image 1. Ocean View Park in 2006, a well-maintained and clean beach.

5. Virginia Beach Department of Public Health

5. A. Virginia Beach and Associated Bay Beaches

The Virginia Department of Health (VDH) monitors both oceanfront and bayside beaches in a section stretching from the Chesapeake Bay Bridge Tunnel, east to Cape Henry and south to Back Bay Beach (some 28 miles of shoreline). The bayside beaches suffered some minor hurricane damage in 2003 but had been fully restored by the 2004 swimming season. The ocean beaches are the most popular in Virginia, the bayside beaches considerably less so. The *Enterococcus* counts at the ocean-side beaches are typically less than 10 CFU/100 mL and, in 2006, 97% of the counts from the weekly VDH samples collected at the ocean-side beaches were less that 10 CFU/100 mL.

Twenty-four samples were collected offshore weekly from a police boat by VDH staff during 2004 and there were no swimming advisories that summer. In 2005 the sampling arrangements were changed and the VDH weekly samples were collected in the surf, a much preferable approach. There was only one swimming advisory in 2005 and the single advisory (63rd Street in August) was apparently due to a pumping problem in a sewer line rather than from any type of persistent fecal pollution. No samples from that advisory were sent to the Virginia Tech (VT) lab for source tracking. In 2006 there were three advisories at Virginia Beach, one on 5/16 at 63rd Street, one on 5/23 at 78th Street, and one on 8/1 at 63rd Street. No plates or water samples were sent to the VT lab from any of these advisories. There are two open storm drains that regularly pump groundwater onto the beach at both locations where the advisories occurred (see Images 1 and 4). These are the only two remaining open pumped discharges on the coastline at Virginia Beach. Discharges from all other pump stations between 16th Street and 42nd Street are located approximately two thousand feet offshore and should not impact inshore water quality in the surf zone.

Prior to the summer of 2005, the beaches from Sandbridge to Fort Story and the beaches fronting the Chesapeake Bay in Virginia Beach had never been closed due to contamination by fecal bacteria. However, since samples were gathered from a boat in 2004 and before, samples collected away from the shore were highly unlikely to yield high counts or to be representative of shore conditions where most of the recreational use occurs. Samples taken on August 9, 2005, produced enterococci levels that exceeded the primary recreational contact limit at the sampling stations located at 45th Street and 63rd Street. VDH posted advisories for these two sections of the beach and the advisories were lifted on August 12th. In May 2006, the beach section represented by the 63rd Street sampling station was posted on May 16th (150 CFU/100 mL) and the section represented by the 78th Street sampling station was posted on May 23rd (150 CFU/100 mL). The two beach closures in the two weeks prior to the Memorial Weekend beginning of beach season caused concern among City Officials. Shortly thereafter, the City staff developed the North Beach Storm Water Quality Plan of Action to develop strategies to prevent additional beach closures. The third beach closure in 2006 was on August 2, based on the results at the 63rd Street monitoring station (170 CFU/100 mL). All three 2006 advisories were removed within two days.

The North Beach Stormwater Quality Plan of Action included the development and implementation of a sampling plan within the stormwater drainage system along Atlantic Avenue. The City of Virginia Beach (CVB) contracted with the Hampton Roads Sanitation District (HRSD) to provide the sampling and testing. The plan included the

sampling and testing of water in various manholes within the Atlantic Avenue Drainage Basin from 52nd street to 89th Street and in the wet wells of the stormwater pump stations. Sampling and testing the waters discharging onto the beach were included in the plan. VT staff also participated in the plan of action and assisted HRSD staff in collection and analysis of beach, wet wells, discharging waters, and storm drain samples as part of the VT contract with VDH in 2006.

HRSD and VT began sampling and testing water in the storm system on June 8, 2006, with samples collected twice a week through July 31, 2006. The sampling stations include the wet wells at the stormwater pumping stations located in the median of 79th Street and 64th Street and at 42nd Street, the boardwalk and 16th Street, and the boardwalk and various structures within the piped storm drainage system between 54th Street and 89th Street. Stormwater samples were also taken at the outfall onto the beach at 79th Street and 64th Street. As of August 1, 2006, the sampling was reduced to once a week through September 30, 2006. Samples were transported to the HRSD and/or the VT laboratories for analysis for fecal coliform, enterococci and fluorescent material. The 79th Street outfall is located on the seaward side of the dune line approximately three hundred fifty feet (350') shoreward of the wave wash zone of the ocean. Stormwater discharges from this outfall and cuts a path through the normally dry sand to the wash zone (Images 4 – 7). At 64th Street, samples were taken at the washed out area near the mouth of the discharge pipe in an area formerly inundated by storm water, and in the wash zone due east of the outfall (Images 1 – 3).

Field Investigation of Storm Drains

Storm drainage structures along Atlantic Avenue and on the connecting side streets from 89th Street to 54th Street were visually inspected for evidence of contamination. The HRSD and VT personnel were looking for contamination indicators including: 1) water flowing in the pipes during dry weather, 2) slime buildup within the structure, 3) excessive sediment in the pipes or structures, 4) excessive infiltration, 5) cloudy and discolored water or turbidity in the water, and 6) septic odors. At locations where there were one or more indicators suggesting possible contamination within the storm drain, inspections of the storm drains were performed in the vicinity of the contamination.

The goal of the North Beach Action Plan is to reduce and/or eliminate beach closures. As a part of this effort, any bacterial contribution to the ocean water quality is to be minimized. The sequence for the investigation of the storm system and its impact on ocean water quality is as follows. If the ocean water quality standard is not met, any contribution to the degradation of water quality from stormwater must be coming from the outfalls at 64th Street and 79th Street. If the flows from these outfalls are clean, then the ocean water quality can not be impacted by the storm drainage system. If the flows from the outfalls do not meet water quality standards, the water quality in the wet wells of the pump station or in the force mains have to be the source. If the water quality in the wet wells is substandard, then the source must be in the gravity drainage system. This report follows this sequence in that discussion of the outfalls will precede the discussion of the wet wells and the wet well discussion will precede the gravity storm drains.

Records of physical conditions including tides, wind direction and speed and rainfall at the time and date of sample collection were compared to the enterococcus levels in an attempt to establish a correlation between the indicator bacteria and one or

more of the physical parameters (Table 1A). VDH collected samples on Tuesday mornings during the beach season in 2006 and there were 20 sampling dates at the 78th Street sampling station and 21 dates at the 63rd Street station from May 16 through September 29, 2006. This represents a period of nineteen weeks. One additional sampling day was added to the 78th Street station and two additional sampling days were added to the 63rd Street station. The additional samples were collected following the dates where the *Enterococcus* levels exceed the standard of 104 CFU/100 mL. *Enterococcus* levels of ten (10) or less were recorded on nineteen (19) of the twenty (20) dates at 78th Street station and seventeen (17) of the twenty-one (21) dates at 63rd Street. For initial comparison purposes, only results of greater than 10 CFU/100 mL were considered.

Table 1A lists the VDH sampling dates, *Enterococcus* levels, tidal conditions, wind speed and direction and rainfall on the day of the sample and the three preceding days where the counts exceeded the regulatory standard. For tide levels and wind data, the time of the VDH sample was assumed to be 10 AM.

Table 1A. Conditions on dates when the counts were greater than 10 CFU/100mL.

Sampling		*Enterococcus*			
Date	Location	CFU/100 mL	Tide	Wind	Rainfall (inch)
5/16	63rd Street	150	H 10:43 AM	SW–7	0.00, 0.90, .038, 0.00
5/23	78th Street	150	L 11:05 AM	Calm	0.00, 0.00, 0.00, 0.00
	63rd	75	L 11:05 AM	Calm	0.00, 0.00, 0.00, 0.00
6/27	63rd Street	41	H 09:51 AM	SW-5	2.24, 2.24, 0.02, 0.09
8/01	63rd Street	170	H 01:21 PM	Calm	0.00, 0.00, 0.00, 0.00

The higher *Enterococcus* levels occurred at or near high tide on two occasions, at or near low tide on one occasion, and at mid-tide range on an incoming tide once. In all cases, the wind was calm or mildly from the southwest (which would indicate small waves). On two occasions there were significant rainfalls prior to the sampling event, and two occasions where there was no rainfall prior to the sampling event. Given the limited number of data points, no relationship can be established between the physical conditions and the *Enterococcus* levels.

Image 1. 64th Street Outfall on July 20, 2006, when the 63rd Street station pump was off.

Image 2. 64th Street Outfall on July 20, 2006, when the 63rd Street station pump was on.

Image 3. 64th Street Outfall on July 20, 2006; the discharge drains down the beach.

Image 4. 79th Street Outfall on July 20, 2006, when the 78th Street station pump was off.

Image 5. 79th Street Outfall on July 20, 2006, when the 78th Street station pump was on.

Image 6. 79th Street Outfall on July 20, 2006; the discharge draining down the beach.

Image 7. 79th Street Outfall on July 20, 2006; the discharge down the beach near the ocean, with children playing in the discharge.

Evaluation of Stormwater Quality (Table 1)

If stormwater was contributing to the degradation of the ocean water to the extent that the beaches have been closed, the contaminated stormwater must be coming from the outfall at 79th Street or 64th Street. In order to establish a correlation between the stormwater discharging onto the beach and the ocean water quality, samples were taken at the out falls and in the flowing water at 64th Street and 79th Streets on the days that the ocean samples were collected at 63rd Street and 78th Street by VDH. The dates of the coincident sampling were June 13th, June 20th, June 27th , July 11th , July 18th, July 25th, August 8th, August 15th, August 22nd and August 29th. The ocean samples at these locations were collected by VDH in the morning of these dates. The wet well and outfall samples also were collected in the morning of these dates (Table 1).

At the 78th Street sampling station, no *Enterococcus* level exceeded 10 CFU/100 mL for the period from May 16 through September 29, 2006 Most reported levels were <10 CFU/100 mL (Table 1). Enterococci levels at the outfall and the downstream flow of stormwater at 79th street varied from a high of >16,700 CFU/100 mL to a low of 18 CFU/100 mL on the dates listed above. The *Enterococcus* level at the outfall or in the flow downstream of the outfall exceeded 500 CFU/100 mL on three dates (June 20th - >16,700 CFU/100 mL, June 27th - 6,500 CFU/100 mL and July 18th – 767 CFU/100 mL).

Similarly, at 63rd Street, on days of coincident sampling, only one sample exceeded the level for *Enterococcus* of <10CFU/100 mL (Table 1). On June 27th, the *Enterococcus* level was recorded at 41 CFU/100 mL. Enterococci levels at the outfall

and the downstream flow of stormwater at 64th street varied from a high of 2,300 CFU/100 mL to a low of 18 CFU/100 mL on the dates listed above. The *Enterococcus* level at the outfall or in the flow downstream of the outfall exceeded 500 CFU/100 mL once, on June 27th – 2,300 CFU/100 mL. The *Enterococcus* level at this station was recorded to be 170 CFU/100 mL on August 1, 2006. Unfortunately, samples were not taken in the stormwater system on that day. However, based on photos of the discharge site at 64th Street taken on August 3rd, it is evident that the storm water discharge at the 64th street outfall infiltrated the sand and did not flow to the ocean (but subsurface infiltration into the ocean is a possibility).

Regarding weather conditions during the sampling scenario in Table 1, on June 20th the recorded rainfall was 0.22 inches and the wind speed and direction at 10 AM was West at 8 mph. On June 27th, the recorded rainfall was 2.24 inches and the wind speed and direction at 10 AM was Southwest at 5 mph. On July 18th, the recorded rainfall was 0.0 inches and the wind was calm. Given the varying levels of bacteria in the outfall stream and the effectively zero bacteria levels in the ocean at the sampling stations, no correlation can be drawn between the bacteria in the stormwater discharge and the sampled water quality, based on the numbers of samples that were taken and the results of the fecal indicator counts that were obtained. However, after precipitation events, the numbers of fecal bacteria in the wetwells, at the outfall of the two discharges, and downstream (DS) from the two discharges are sufficiently high to impact the swimming areas where VDH collected samples. That so few advisories occurred at these sites was probably due to several factors that included dilution of the discharges by mixing in the surf zone, there were only a few substantial precipitation events in the summer of 2006, and VDH sampling was not done directly in front of the discharge areas in the swash zone.

Table 1

COMPARISON OF VDH SAMPLING VS STORM WATER SAMPLING

		VDH			In Wetwell		At Outfall		DS of Outfall	
Date	Location	Entero MPN/ 100 Ml	F Coliform MPN/ 100 Ml	E.Coli MPN/ 100 Ml	Entero MPN/ 100 Ml	F Coliform MPN/ 100 Ml	Entero MPN/ 100 Ml	F Coliform MPN/ 100 Ml	Entero MPN/ 100 Ml	F Coliform MPN/ 100 Ml
6/13/06	78th St	<10	<10	<10						
	79th St				82	27				
	63rd St	<10	<10	<10						
	64th St				560	600				
6/20/06	78th St	10	140	120						
	79th St				410	1,330	>16,700	2,200		
	63rd St	<10	<10	<10						
	64th St				1,090	5,400	470	1,600		
6/27/06	78th St	10	<10	<10						
	79th St				1,120	15,900	6,500	17,300	5,000	12,600
	63rd St	41	10	10						
	64th St				2,500	6,300	2,300	10,100	1,580	9,300
7/05/06	78th St	<10	<10	<10						
	79th St				NS	NS	NS	NS	NS	NS
	63rd St	<10	<10	<10						
	64th St				NS	NS	NS	NS	NS	NS
7/11/06	78th St	<10	<10	<10						
	79th St				45	36	NS	NS	NS	NS
	63rd St	<10	<10	<10						
	64th St				109	109	NS	NS	NS	NS
7/18/06	78th St	<10	<10	<10						
	79th St				109	420	320	2,900	767	>6,200
	63rd St	<10	<10	<10						
	64th St				480	5,500	118	1,060	NS	NS
7/25/06	78th St	<10	<10	<10						
	79th St				36	118	109	360	105	445
	63rd St	<10	<10	<10						
	64th St				210	240	36	36	NS	NS
8/01/06	78th St	<10	<10	<10						
	79th St				NS	NS	NS	NS	NS	NS
	63rd St	170	<10	<10						
	64th St				NS	NS	NS	NS	NS	NS
	45th St	10	<10	<10						
8/08/06	78th St	<10	<10	<10						
	79th St				27	<10	27	36	NS	NS
	63rd St	<10	<10	<10						
	64th St				420	100	18	36	NS	NS
8/15/06	78th St	<10	<10	<10						
	79th St				18	<10	36	45	48	100
	63rd St	<10	<10	<10						
	64th St				1,110	36	82	1,040	NS	NS
8/22/06	78th St	<10	<10	<10						
	79th St				209	18	91	270	335	2,500
	63rd St	<10	<10	<10						
	64th St				91	5,000	73	27	NS	NS
8/29/06	78th St	<10	<10	<10						
	79th St				155	45	18	91	155	360
	63rd St	<10	20	20						
	64th St				52	81	36	260	NS	NS
9/05/06	78th St	10	10	10						
	79th St				155	1,020	420	4,100	5,200	>20,000
	63rd St	10	30	10						
	64th St				220	4,200	NS	NS	NS	NS
9/12/06	78th St	<10	<10	<10						
	79th St				27	145	3,700	5,600	NS	NS
	63rd St	<10	<10	<10						
	64th St				52	280	82	1,040	NS	NS
9/19/06	78th St	10	<10	<10						
	79th St				9	73	27	350	NS	NS
	63rd St	10	<10	<10						
	64th St				<10	136	NS	NS	NS	NS
9/25/06	78th St	10	52	10						
	79th St				664	450	1,570	1,500	NS	NS
	63rd St	10	<10	<10						
	64th St				540	1,370	NS	NS	NS	NS

Stormwater Pump Station Sampling Results (Wet Wells, Table 2)
Samples from the wet wells of the stormwater pumping stations at 79th Street, 64th Street, 42nd Street, and 16th Street were collected and analyzed on a twice weekly basis from June 13 through July 27, 2006, and weekly from August 3 through September 26, 2006. In most cases, the water in the wet wells had been standing for a period of time and the samples were representative of only the volume of water in the wet well. The 16th Street and the 42nd Street stormwater pumping stations were installed as a part of the beach hurricane protection project constructed by the Corps of Engineers in 1995. The discharges from these stations are piped approximately 2,000 feet into the ocean and are not believed to have contributed to the *Enterococcus* levels on the dates the advisories were posted (but this may or may not be the case). Since the storm drainage system discharges into the saltwater in the ocean, both fecal indicator bacteria, *E. coli* (standard is 235 CFU/100 mL) and *Enterococcus* (standard is 104 CFU/100 mL) are used to evaluate the water in the storm system and storm pump station wet wells.

79th Street Station - Samples from the wet well of the 79th Street stormwater pump station were fairly clean during most sampling events (Table 2). Of the 23 samples collected and analyzed at this station, 11 of the samples were above the *Enterococcus* standard and 8 samples were above the *E. coli* standard. The highest *Enterococcus* and *E. coli* levels, 1,120 and >15,900 CFU/100 mL, respectively, occurred on June 27th following a rainfall of 3.97 inches on July 26th and 2.35 inches on the 27th, the day the samples were collected. The *Enterococcus* level exceeded 500 CFU/100 mL three times, twice in the month of June and once in September. Likewise, the *E. coli* levels exceeded 1,000 CFU/100mL three times, twice in June and once in September.

64th Street Station - Of the 23 samples collected and analyzed at this station, 17 of the samples were above the *Enterococcus* standard and 15 samples were above the *E. coli* standard. The highest *Enterococcus* and *E. coli* levels, 2,500 and >6,300 CFU/100 mL, respectively, occurred on June 27th following a rainfall of 3.97 inches on July 26th and 2.35 inches on the 27th, the day the samples were collected. The *Enterococcus* level exceeded 500 CFU/100 mL seven times, five in the month of June and twice in August. The *E. coli* levels exceeded 1,000 CFU/100mL eleven times, six in June, twice in July, once in August, and twice in September.

60th Street Station - Of the 23 samples collected and analyzed at this station, 11 of the samples were above the *Enterococcus* standard and 7 samples were above the *E. coli* standard (the fewest number over the standard for both indicator organisms). The highest *Enterococcus* levels were 2,400 CFU/100 ml on August 3, and the highest *E. coli* levels were 3,100 CFU/100 mL on September 5. Neither of these highest counts was associated with a rainfall event. The *Enterococcus* level exceeded 500 CFU/100 mL six times, four in the month of June, once in July, and once in August. The *E. coli* levels exceeded 1,000 CFU/100mL three times, twice in June and once in September.

42nd Street Station – This storm water pump station is located on the boardwalk at the east end of 42nd Street and discharges directly into the ocean approximately 2000 feet offshore. No samples were collected at this site in September. Of the16 samples

collected and analyzed at this station, 13 of the samples were above the *Enterococcus* standard and 14 samples were above the *E. coli* standard. The highest *Enterococcus* and *E. coli* levels, >11,800 and >20,000 CFU/100 mL, respectively, occurred on June 27th following a rainfall of 3.97 inches on July 26th and 2.35 inches on the 27th, the day the samples were collected. The *Enterococcus* level exceeded 500 CFU/100 mL five times, four in the month of June and once in August. The *E. coli* levels exceeded 1,000 CFU/100mL nine times, four in June, three times in July, and twice in August. The *E. coli* counts were greater than 20,000 CFU/100 mL three times and greater than 12,100 CFU/100 mL one additional time (August 8). These high measurements for both fecal indicators showed no correlation with rainfall.

Table 2
Bacterial Levels In Wet Wells

	79 St		64 St		60 St		42 St		16 St		
DATE	Entero	EC	Entero	EC	Ent	EC	Ent	EC	Ent	EC	Rain
8-Jun	54	**270**	**831**	**2100**	**831**	**900**	NS	NS	**112**	**2700**	0
13-Jun	82	27	**560**	**600**	**600**	100	**200**	**220**	**540**	**>6300**	0.27
15-Jun	**1015**	**691**	**2000**	**1530**	**955**	**1010**	**1430**	**1680**	**>9300**	**1520**	5.11
20-Jun	**410**	**1330**	**1090**	**5400**	**800**	**1800**	**1380**	**>20,000**	**>6800**	**>20,000**	0
22-Jun	27	173	**440**	**2100**	NS	NS	**260**	**864**	**2300**	**>7500**	0.22
27-Jun	**1120**	**>15900**	**2500**	**>6300**	NS	NS	**>11,800**	**>20,000**	**>13,000**	**>20,000**	2.35
29-Jun	**250**	**440**	**144**	**1460**	NS	NS	**1070**	**4900**	**991**	**>7000**	4.48
6-Jul	27	45	82	45	NS	NS	**127**	**590**	**370**	**360**	0
11-Jul	45	36	**109**	109	**1200**	73	**795**	<10	**1500**	**>20,000**	0
13-Jul	<10	<10	18	145	NS	NS	100	91	**173**	**4400**	0
18-Jul	**109**	**420**	**480**	**5500**	NS	NS	**250**	**>20,000**	36	**2200**	0.32
20-Jul	**109**	173	**164**	**2200**	**127**	**900**	64	**430**	27	**>10,100**	0
25-Jul	36	118	**210**	**240**	NS	NS	**390**	**2000**	**320**	**>18,000**	0.05
27-Jul	27	27	**145**	**260**	NS	NS	**155**	**1740**	64	**>20,000**	0
3-Aug	**182**	73	**600**	182	**2400**	119	55	**1260**	27	**1750**	0
8-Aug	27	<10	**420**	100	**410**	45	**918**	**>12,100**	**990**	**>9,600**	0
15-Aug	18	<10	**1110**	36	55	73	NS	NS	82	**>16,100**	0
22-Aug	**209**	18	91	**5000**	**127**	45	**330**	**855**	100	**>20,000**	0
29-Aug	**155**	45	52	81	73	91	NS	NS	91	**>13,700**	0
5-Sep	**155**	**1020**	**220**	**4300**	**280**	**3100**	NS	NS	**1340**	**>20,000**	0
12-Sep	27	145	52	**280**	27	**280**	NS	NS	45	**1550**	0
19-Sep	9	73	<10	136	27	145	NS	NS	18	**1700**	0.22
26-Sep	**664**	**450**	**540**	**1370**	**250**	**664**	NS	NS	**>10,400**	**15,100**	1.24

In Table 2 the bacterial levels have been highlighted in bold that exceed the single sample maximums for *Enterococcus* (Ent) and *E. coli* (EC). The blocks not in bold are below the single sample maximum standard for recreational contact (>104 for *Enterococcus* and >235 for *E. coli*). Although there are some extremely high levels of both enterococci and

fecal coliforms reported in these wet wells, and it is anticipated that testing with microbial source tracking by the VT lab in 2007 will aid in determining the sources of these fecal bacteria.

16th Street Station - This storm water pump station is located on the boardwalk at the east end of 16th Street and discharges directly into the ocean approximately 2000 feet offshore. Of the 23 samples collected and analyzed at this station, 14 of the samples were above the *Enterococcus* standard and all 23 samples were above the *E. coli* standard. The highest *Enterococcus* and *E. coli* levels, 13,000 and >20,000 CFU/100 mL, respectively, occurred on June 27th following a rainfall of 3.97 inches on July 26th and 2.35 inches on the 27th, the day the samples were collected. The *Enterococcus* level exceeded 500 CFU/100 mL ten times, six in the month of June, once in July, once in August, and twice in August. The *E. coli* levels exceeded 1,000 CFU/100mL 22 of 23 times, all except July 6. The *E. coli* counts were greater than 20,000 CFU/100 mL six times and greater than 10,000 CFU/100 mL five additional times. These high measurements for both fecal indicators showed no correlation with rainfall.

Plans for Virginia Beach in 2007

In 2007, communications will be maintained with the VDH staff so that additional sample collections can be made (by either VDH or VT staff) in a "quick response" mode whenever advisories are posted in an attempt to relate advisories to certain conditions or events such as tides, storms, wind direction, and bird patterns. This should help explain the origins of high *Enterococcus* counts that may result in sporadic advisories at any of the Virginia Beach locations. Based on the successful results of the blind test with HRSD and CVB, the VT lab will continue to work with HRSD and will employ source tracking in 2007 to determine the sources of the enterococci in the discharges, outfalls, beach sand, and wet wells. Also, a grid system where nine samples are collected for each beach segment, 3 transects by 3 depths, will be used after major precipitation events to collect samples in the ocean in front of the outfalls. This grid system was successfully used by the VT staff at other beaches in 2005. Source tracking, with confidence obtained from the blind study, will compare the enterococci from the wet wells, pump stations, discharges, and ocean water. In addition, in 2007 the beach sand within the discharge areas will be sampled to determine if it is acting as a reservoir for enterococci where either re-growth or longer-term survival (that could impact beach water quality) might occur.

5. B. Virginia Tech, Virginia Beach, and Hampton Roads Sanitation District (HRSD) Bacterial Source Tracking Blind Challenge Test Results

Introduction

HRSD prepared 24 samples for a blind (challenge) study to determine if Bacterial Source Tracking (BST) could correctly identify bacterial contaminants as being of a human (sewage) or a non-human (gulls and/or dogs) source, and also to identify gulls, dogs, and various combinations of the three sources together. The samples were analyzed by Dr. Hagedorn's BST program at Virginia Tech. This report describes a statistical analysis and summary of the results.

Results

The results of the blind study are presented in Table 1. These data indicate that the source of the bacteria was incorrectly attributed 6 times out of the 24 samples, including 3 false positives and 3 false negatives. The false attributions included samples with low (<120/100mL, 4 samples) and high (>15,000/100mL, 2 samples) *Enterococci* counts. In all cases where a sample was wrongly identified, a duplicate sample ("dup") was correctly identified. Only the samples with bacteria of human origin only were all correctly identified. That is, there was at least one wrong attribution in any of the tested mixtures and animal sources. The first set of results was submitted to HRSD on 12/15, where the goal was to identify each blind into one of six categories (chance of 1 in 6 or 16.7% based on random guessing, as the blind set was composed equally of four entries from each of the six categories). The ID of the blinds was released on 12/20. The results were:

Human only	4 correct of 4 (100%)
Dog only	2 correct of 4 (50%)
Gull only	3 correct of 4 (75%)
Animal dominant	3 correct of 4 (75%)
Human 50:50	3 correct of 4 (75%)
Human dominant	3 correct of 4 (75%)
Totals	**18 correct of 24 (75%)**

The host-origin library performed the best with human only (100%) and the worst with dog only (50%). These results demonstrate where improvements need to be made. The second set of results was submitted to HRSD on 12/20, where the goal was to identify each blind into one of two categories, human or non-human. The ID of the blinds was released later on the same day, 12/20). The results were:

Human	**14 correct of 16 (87.5%)**
Non-human	4 correct of 8 (50%)
Totals:	**18 correct of 24 (75%)**

Table 1. BST Blind Test Results.

ID	Sample Site	Enterococci #/100mL	True Result	BST Result	Correct ID?
4	50% Human Mix dup	77	Present	Present	TRUE
16	50% Human Mix	71	Present	Absent	FALSE
23	50% Human Mix	14800	Present	Present	TRUE
9	50% Human Mix dup	20000	Present	Present	TRUE
3	Animal Dom. Mix	83	Present	Absent	FALSE
13	Animal Dom. Mix dup	84	Present	Present	TRUE
21	Animal Dom. Mix	24000	Present	Present	TRUE
19	Animal Dom. Mix dup	17100	Present	Present	TRUE
8	Dog Only	105	Absent	Present	FALSE
1	Dog Only dup	107	Absent	Absent	TRUE
22	Dog Only	17000	Absent	Present	FALSE
18	Dog Only dup	19600	Absent	Absent	TRUE
7	Gull Only	117	Absent	Present	FALSE
12	Gull Only dup	97	Absent	Absent	TRUE
5	Gull Only	22000	Absent	Absent	TRUE
14	Gull Only dup	26000	Absent	Absent	TRUE
15	Human Dom. Mix	54	Present	Present	TRUE
24	Human Dom. Mix dup	51	Present	Present	TRUE
20	Human Dom. Mix	17200	Present	Absent	FALSE
10	Human Dom. Mix dup	14400	Present	Present	TRUE
11	Human Only	47	Present	Present	TRUE
2	Human Only dup	34	Present	Present	TRUE
6	Human Only	14400	Present	Present	TRUE
17	Human Only dup	14400	Present	Present	TRUE

Statistical Considerations

From a statistical viewpoint, the identification of bacterial sources from human or non-human sources can be considered a binomial experiment (e.g., a coin toss) with the probability of success p (i.e., the probability of a correct ID). A point estimator P of the proportion of samples that can be correctly attributed to a human or non-human source can then be determined based on the outcome of the blind study. That is, $P = X / n$, where n is the number of observations (i.e., the sample size) and X is the number of observations belonging to a class of interest, i.e., the class of samples that were correctly identified. With 18 correct IDs out of 24 samples P becomes 0.75.

To determine “how good” the estimate for P is, it is necessary to construct a confidence interval on the proportion of correctly identified samples. The sampling distribution of P is approximately normal. Then an approximate $100(1-\alpha)$ percent confidence interval on the proportion p can be constructed as follows:

$$P - z_{\alpha/2}\sqrt{\frac{P(1-P)}{n}} \le p \le P + z_{\alpha/2}\sqrt{\frac{P(1-P)}{n}}$$

$z_{\alpha/2}$ is the upper $\alpha/2$ percentage point of the standard normal distribution. For the blind study results, the 95% confidence interval becomes:

$$0.75 - 1.96\sqrt{\frac{0.75(1-0.75)}{24}} \le p \le 0.75 + 1.96\sqrt{\frac{0.75(1-10.75)}{24}}$$

Therefore the 95% confidence interval on the proportion of correctly identified samples using BST is between 58% and 92%.

To illustrate what these estimates mean with respect to the reliability of BST for identifying bacteria from human or non-human sources, consider a future sampling event with 10 samples (n = 10). The probability of identifying all 10 samples (x = 10) correctly can be computed from the probability mass function of the binomial distribution:

$$P(X = x) = f(x; p, n) = \binom{n}{x} p^x (1-p)^{n-x}, x = 0, 1, \ldots n$$

In the best case scenario, using the probability of a correct identification of an individual sample of p = 92%, the probability of correctly identifying all 10 samples becomes 85%. In the worst case (p = 58%), it is 45%. Under the best case, the confidence of being correct is quite high (85%). Under the worst case it is close to 50%. This is still a wide range, but cannot be reduced with the blind set that was used in this study. A variety of different statistical analyses and host-origin library alterations are now being examined to see if some analytical procedure can be identified that will provide better results. If this evaluation of analytical procedures is successful, the best procedures will be tested with a second blind set that will be designed so that the probability-of-success range can be improved.

For the six blinds that were incorrect, 3 were false positives (identified as human when they were not), and three were false negatives (identified as non-human when they were). It would be correct to assume that the odds were 1 in 2, or 50% based on random guessing, of being right on any one sample for a human vs. non-human split. However, the probability of being right over the entire blind set was not 50%, as the human and nonhuman blinds were not evenly divided between 12 and 12, but rather as 16 and 8. The 50:50 chance of being correct over the entire set is only correct if 12 of the blinds were human and 12 were not. If the IDs had been assigned to the blinds in a random fashion, based on 50:50, the score would depend on how the random assignments were made. For example, assigning the odd-numbered blinds as human and the even-numbered blinds as non-human, then 14 would have been correct (58.3%). If the order had been reversed, assigning the even-numbered blinds as human and the odd-numbered blinds as non-human, then 10 would have been correct (41.7%). Assigning the first 12 as human and second 12 as non-human would have resulted in 12 (50%) correct. Our results

(75% for human or non-human) were above any of the random assignments; this is especially true for our 75% score for the six choices (6-way split), where the probability of being correct based on guessing was only 1 in 6, or 16.7%.

There have been two method comparison studies completed to date. The first was sponsored by the Southern California Coastal Water Research Project (SCCWRP). This study resulted is a series of seven publications, all in the same issue of *Journal of Water and Health.* Of the seven papers, three are related to this blind study:

Harwood, V.J., Wiggins, B., Hageodorn, C., Ellender, R.D., Gooch, J., Kern, J., Samadpour, M., Chapman, A.C.H. and Robinson, B.J. 2003. Phenotypic library-based microbial source tracking methods: efficacy in the California collaborative study. J. Wat. Health 1: 153-166.

Myoda, S.P., Carson, C.A., Fuhrmann, J.J., Hahn, B., Hartel, P.G., Kuntz, R.L., Nakatsu, C.H., Sadowsky, M.J., Samadpour, M., and Yampara-Isquire, H. 2003. Comparing genotypic bacterial source tracking methods that require a host origin database. J. Wat. Health 1: 167-180.

Stewart, J. R., Ellender, R. D., Gooch, J. A., Jiang, S., Myoda, S. P., and Weisberg, S. B. 2003. Recommendations for microbial source tracking: lessons learned from a methods comparison study. J. Water Health 1: 225-231.

The second comparison study was sponsored by the U.S. Geological Survey (USGS), and resulted in one publication:

Stoeckel, D.M., Mathes, M.V., Hyer, K.E., Hagedorn, C., Kator, H., Lukasik, J., O'Brien, T.L., Fenger, T.W., Samadpour, M, Strickler, K.M., and Wiggins, B.A. 2004. Comparison of seven protocols to identify fecal contamination sources using *Escherichia coli*. Environ Sci. Technol. 38: 6109-6117.

Our HRSD-VT blind test was a combination of both the SCCWRP and USGS studies. In the USGS study, participants were provided the actual pure cultures for the blinds (the source of each was not identified); in the SCCWRP study, fecal matter from the different sources was added to marine, or brackish, or freshwater and sent to participants as blinds. In our HRSD-VT blind study, pure cultures were added to buffer in different ratios or alone, a hybrid between USGS and SCCWRP. The results for the same methods that were used in this study (antibiotic resistance analysis (ARA) and polymerase chain reaction (PCR) are summarized as follows:

SCCWRP Study (2003)	% Correct	
Method	Human-nonhuman	Specific categories
ARA	45.4%	25.4%
REP-PCR	67.0%	44.0%

USGS Study (2004)		
Method	Human-nonhuman	Specific categories
ARA	39%	27%
BOX-PCR	48%	22%
REP-PCR	61%	26%
Comparing the above to the HRSD-VT results (2006)		
VT-HRSD	75%	75%

BOX-PCR was not included in the SCCWRP study. Several other methods were included in both comparison studies, with mixed results. For example, Ribotyping (RT) and Pulsed-field Gel Electrophoresis (PFGE) were used in both method comparison studies, and they performed better that ARA and PCR, but were still not superb. Both RT and PFGE scored in the 60s and 70s on the USGS study, slightly lower in the SCCWRP study. However, both of these methods are very expensive (4X to 5X our price), require costly equipment and highly trained laboratory personnel.

Lastly, for one of our VT source tracking projects that we performed a few years ago, we tested our host origin library with a blind challenge set and the percent correct rates were in the 50s and 60s, better than SCCWRP and USGS results, but not as good as we did in the present HRSD-VT study. We are making progress. This research has been submitted for publication and is currently under review.

Graves, A. K., C, Hagedorn, A. Brooks, R. L. Hagedorn, and E. Martin. Microbial Source Tracking in a Rural Watershed Dominated by Cattle. Submitted to *Journal of Water Research* for 2007 publication.

Conclusion

Assembling a host-origin library with few isolates from a large number of samples collected on a frequent basis over the three year period where VT and VDH have been cooperating on examining water quality at Virginia's public beaches, resulted in a host-origin library that was stable for at least that period, was geographically representative (high source category rates of correct classification in the library and agreement on water sample results by both 2-source [human vs. non-human] and 4-source libraries [humans, birds, dogs, wildlife]) and, most importantly, the library was largely successful in source identification on the blind challenge test.

7. Eastern Shore Health District

7. A. Eastern Shore Beaches

The Eastern Shore Health District monitored four different beaches on both the ocean-side (1 beach) and bayside (3 beaches) of the peninsula in 2004, 2005, and 2006. Assateague Beach National Seashore is a large ocean-side beach on the northern part of the peninsula with four sampling locations, evenly distributed down a 4 mile shoreline. Guard Shore beach is a small bayside beach with two sampling locations, also on the northern part of the peninsula. Kiptopeke Beach is found in a state park with the same name on the Chesapeake Bay side of the southern peninsula. Kiptopeke has two sampling locations north of its public boat launch ramp. Cape Charles Harbor is a bayside beach located above Kiptopeke, on the waterfront in the town of Cape Charles. There are four monitoring locations and the beach is bordered on the north by several jetties and storm drain outfalls. The eastern shore beaches were not seriously impacted by Hurricane Isabel in 2003, and there were no advisories in 2004 or 2006. There were two advisories posted at Guard Shore Beach in 2005, one in June and one in July. Microbiological water quality monitoring is performed using membrane-filtration by the VDH – Division of Shellfish Sanitation lab in Accomac, VA. No samples from Assateague National Seashore, Kiptopeke State Park, or Cape Charles exceeded the *Enterococcus* standard for the summer of 2006, and thus no advisories were posted on these beaches. No fluorescent signal (optical brighteners) was detected in any of the samples obtained from the beaches of the Eastern Shore in 2006.

Assateague Island National Seashore

On the Assateague National Seashore, the U.S. Park Service provides self-contained sanitary facilities (pumped and hauled on a regular basis) and showers at various

locations adjacent to the parking lots, and pets are not allowed on Assateague Island. Trash receptacles are located along the beach and are emptied regularly. There are no piers or structures that might attract shore birds. With dilution and tides from the open ocean, postings should not be an issue at the National Seashore (see picture above). This is a clean and well maintained beach. Only 1 of 17 VDH samples in 2006 were above 10 CFU/100 mL, and the lone sample was below 50 CFU/100 mL.

Guard Shore Beach

Guard Shore Beach, eastern shore of Chesapeake Bay.

Guard Shore is an undeveloped beach that is a favorite with migrant workers, mainly on weekends (see picture above). With no services at this beach, both human and dog wastes were observed when samples were collected, and birds were attracted to the trash left on the beach. Periodic postings should be expected on Guard Shore, especially if samples are collected near the weekend, when most of the activities on the beach occur. Larger crowds used the beach in 2005 and 2006, as compared to 2004, and more frequent advisories may occur in the future if this trend continues (although there were no advisories in 2006). For the following results, the monitoring was done by the DSS-VDH lab in Accomac and the membrane-filtration plates were shipped to VT (every date where counts above 10 CFU/100 mL were obtained, Table 1).

Table 1. Monitoring and source tracking results for Guard Shore, 2006.

Date	Beach/Counts-CFU/100 mL	Birds	Humans	Dogs	Wildlife	Total
6/15/2006	Guard Shore - 101	12	0	4	0	16
6/29/2006	Guard Shore - 32	10	0	4	2	16
7/13/2006	Guard Shore - 18	10	0	5	1	16
7/27/2006	Guard Shore – 15	11	0	4	1	16
8/10/2006	Guard Shore – 18	13	0	3	0	16
8/17/2006	Guard Shore - 61	10	0	4	2	16
2006	Totals	66	0	24	6	96
2006	Percentages	68.8	0	25.0	6.2	100

The results in Table 1 demonstrate that the major sources of pollution at Guard Shore Beach are birds (68.8%, perhaps in part attracted to trash and litter left on the beach), and dogs (25.0%). Visitors to the beach frequently bring dogs, and dog waste was evident on the beach.

Kiptopeke State Park

Beach at Kiptopeke State Park.

Kiptopeke State Park provides sanitary facilities and dogs are not allowed on the beach. State

Park staff monitor the beach and help maintain a clean beach environment (see picture above). Postings should not be a problem at this beach, and there were no advisories in 2004-2006. Only 2 of 17 VDH samples in 2006 were above 10 CFU/100 mL, and both of these were below 50 CFU/100 mL.

Cape Charles Harbor Beach (The beach at Cape Charles Harbor, looking south).

Cape Charles provides sanitary facilities, but does not ban dogs from the beach. However, no dog wastes were observed on the beach during visits by the VT staff in 2005 and 2006. Numerous storm drains enter the water just north of the beach area (see picture above), and water does flow periodically from these drains, especially during storm events. These storm drains could cause problems for Cape Charles Beach in a wet summer, and should be monitored to assess that possibility (see picture below). For the VDH monitoring counts for Cape Charles in 2006, 7 of 17 samples (41.2%) exceeded 10 CFU/100 mL, but only 3 were above 50 CFU/100 mL (and below 100 CFU/100 mL).

North end of Cape Charles Beach, showing breakwaters and storm drains.

Plans for 2007 on Eastern Shore Beaches

Minimal monitoring by the VT staff will be necessary on the Eastern Shore in 2007. However, continued observation of Cape Charles Harbor storm drain outfalls will be done in 2007, especially around storm events, by VDH staff, and Guard Shore will be examined closer to weekends when the beach is being used. No monitoring at the Eastern Shore, other than what is planned by VDH staff, will be needed in 2007 unless advisories occur.